Office of Hazardous Materials Safety Research and Development (R&D) Public Meeting and Forum Event Summary Report

October 12 – 15, 2021

Executive Summary

The U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration's (PHMSA) Office of Hazardous Materials Safety (OHMS) led a remote public Research, Development & Technology (RD&T) Forum on October 12-15, 2021. The forum focused on presenting the results of recently completed research projects, announcing new project plans, and obtaining stakeholder input on the direction of current and future research projects. Some topics the forum covered include the mitigation of climate change, risk management and mitigation, packaging integrity, emerging technology, and technical analysis to aid risk assessment.

The goals of the RD&T forum were to:

- Inform stakeholders of OHMS's RD&T agenda and present opportunities and challenges to completing program objectives;
- Solicit stakeholder comments related to new research gaps that may be considered for future research topics, particularly in areas associated with energetic materials, safe transportation of energy products, safe containment, and transportation of compressed gases and storage devices, and how these might aid in the mitigation of climate change.

The Forum was composed of four half-day sessions broken up by the topic area. Day 1 of the RD&T forum comprised a variety of government and industry presentations from subject matter experts focused on program overviews and visions for future work (Section 2). The second day of the RD&T forum included government and industry presentations from SMEs focused on Risk Analysis specifically regarding HAZMAT rail incidents, commodity flow survey analysis, GIS, and hazardous material incidents (Section 3). Day 3 of the RD&T forum covered government and industry presentations from SMEs focused on Energy Products, specifically on lithium-ion battery research and thermites (Section 4). Finally, Day 4 of the RD&T forum comprised of government and industry presentations from SMEs focused on Packaging, which included discussions on composite metal foams for HM transportation, and thermo-mechanical responses of FRP composite jacketing (Section 5).

Additionally, all presentations were followed by a question-and-answer (Q&A) section. Each day of the forum concluded with an open discussion with stakeholders to elicit feedback on presented topics and solicit any potential research topics or safety gaps.

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Acronyms and Abbreviations

BAA	Broad Agency Announcement
BTS	Bureau of Transportation
CAAP	Competitive Academic Agreement Program
CANUTEC	Canadian Transport Emergency Centre
CMF	Composite Metal Foam
DOT	Department of Transportation
FHWA	Federal Highway Administration
FRP	Fiber Reinforced Plastic
GIS	Geographic Information System
FTA	Federal Transit Administration
IBC	Intermediate Bulk Container
LNG	Liquefied Natural Gas
MSI	Minority Serving Institution
OHMS	Office of Hazardous Material Safety Research (OHMS)
OPS	Office of Pipeline Safety
PHMSA	Pipeline and Hazardous Materials Safety Administration
R&D	Research and Development
RD&T	Research, Development, and Technology
RFP	Request For Proposal
SBIR	Small Business Innovation Research
SRA	Safety Research and Analysis
TDG	Transportation of Dangerous Goods
UN	United Nations
UNGS	Underground Natural Gas Storage

1 INTRODUCTION AND OVERVIEW

Overview of R&D Forum and goals

The U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration's (PHMSA) Office of Hazardous Materials Safety (OHMS) led a public Research, Development & Technology (RD&T) Forum on October 12-15, 2021. The Forum focused on presenting the results of recently completed research projects, announcing new project plans, and obtaining stakeholder input on the direction of current and future research projects. Some topics the forum covered include the mitigation of climate change, risk management and mitigation, packaging integrity, emerging technology, and technical analysis to aid risk assessment.

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Agenda review

The Forum comprised of four half-day sessions with government and industry presentations on different focus areas. Following presentations were brief question and answer sessions and finally an open discussion amongst attendees. Each day was opened and closed by different OHMS speakers.

Table 1 summarizes the focus for each day of the R&D forum.

Table 1: 2021 R&D Public Meeting and Forum Agenda Summary

Day	Date	Agenda
1	**12 OCT 2021**	Program Overview
2	**13 OCT 2021**	Risk Analysis
3	**14 OCT 2021**	Energy Products
4	**15 OCT 2021**	Packaging

2 DAY 1: PROGRAM OVERVIEW

2.1 Overview

Day 1 focused on "Program Overviews" and opened with remarks from the following PHMSA officials:

- Ms. Yolanda Y. Braxton, Director, Operation Systems, Office of Hazardous Materials Safety

- Mr. Tristan Brown, Acting Administrator, Pipeline and Hazardous Materials Safety Administration
- Mr. William "Bill" Schoonover, Associate Administrator, Office of Hazardous Materials Safety

Opening remarks were followed by five presentations introducing PHMSA's OHMS RD&T Program, PHMSA's Office of Planning & Analytics Program, the Volpe National Transportation System Center, PHMSA's Office of Pipeline Safety Program, and Transport Canada's Transport Dangerous Goods Program.

2.2 Presentations

2.2.1 Presentation 1: Research, Development, and Technology Program Overview

Mr. Andy Leyder, Program Analyst, OHMS RD&T Branch, presented an overview (**Section 7.1.1)** of the OHMS RD&T's programs and activities. Some of the highlights include:

- An overview of the RD&T's different research solicitation types, such as Broad Agency Announcements (BAAs), Small Business Innovation Research (SBIR) program, and Requests for Proposals. BAAs present research topics and challenge the researcher to search for a solution. The SBIR program is for small businesses to engage with PHMSA R&D groups to work on research projects with the end goal of potential commercialization. The last solicitation type is a Request for Proposal (RFP) solicitation through sams.gov and using keywords, "Identifying Hazmat Safety Research Gaps" to submit an RFP.
- The RD&T Branch collaborates and partners with various U.S. agencies such as the Volpe Center, U.S. Naval Research Laboratory, and colleges and universities. The RD&T program reminded the forum attendees that they are open to different types of research collaborations.
- The RD&T Branch has several ongoing and completed projects in its program areas, which are Risk Management, Package Integrity, Emerging Technology, and Technical Analysis to Aid Risk Assessment. As the RD&T Branch moves into FY 2022, the program will continue its research in the above program areas.

2.2.2 Presentation 2: DOT Research and Development Strategic Priorities

Sherry Borener, PHMSA Senior Research Advisor, presented on the overview (**Section 7.1.2**) on the PHMSA Office of Planning & Analytics Program:

- PHMSA promotes the development of innovative global transport safety standards to support alternative and sustainable energy sources, new technologies, and process innovations. PHMSA will also continue its ongoing research efforts in greenhouse gasses and climate change.

- Showcased different initiatives other modal partners are conducting to address climate change, such as the Federal Highway Administration (FHWA) Office of Planning, Environment, and Realty, which is looking into alternative fuel corridors, electric vehicle charging, and renewable energy.
- Presented Federal Transit Administration (FTA) research initiatives on the greenhouse gas emissions estimator tool, bus efficiency enhancements research, and demonstration programs.
- Discussed Federal Aviation Administration's (FAA) program to develop an aviation climate action plan that details U.S. actions to achieve aviation emissions reductions consistent with a pathway to economy-wide net zero emissions.

2.2.3 Presentation 3: Volpe National Transportation System Center Program

Mark Raney, Environmental Engineer, Senior Project Manager, Volpe National Transportation System Center, provided an overview (**Section 7.1.3**) of Volpe's program:

- Volpe Center provides U.S DOT with the capabilities to conduct environmental, economic, and policy analysis, impartial investigations and program evaluations, and knowledge transfer to its U.S. DOT partners.
- Volpe Center also assists DOT with the SBIR program. Volpe works with PHMSA and other DOT modes on awarding contracts to domestic small businesses to pursue research.
- Volpe Center works with OHMS's RD&T program in different support areas such as program management and SME support, research implementation and analysis, and stakeholder outreach and R&D coordination.
- Mr. Raney highlighted several research projects the Volpe Center is supporting OHMS on, including the:
  - Nurse Tank Fatigue Life Analysis
  - Fiber Reinforced Plastic (FRP) Materials for Highway Cargo Tanks
  - Cost of Delay for HAZMAT Rail Incidents.

2.2.4 Presentation 4: Office of Pipeline Safety Research & Development Program

Kandi Barakat, Office of Pipeline Safety (OPS), Research and Development Branch, presented an overview (**Section 7.1.4**) on OPS's R&D program:

- The OPS R&D program includes the Competitive Academic Agreement Program (CAAP), which provides funding towards academic research, SBIR, and inter-agency agreements. OPS's seven research focus areas include:
  1. Pipeline Threat Prevention

2. Pipeline Leak Detection
3. Pipeline Anomaly Detection/Characterization
4. Pipeline Repair, Remediation, and Rehabilitation
5. Liquified Natural Gas (LNG) Safety
6. Underground Natural Gas Storage (UNGS) Safety
7. Alternative Fuels Research to Address Climate Change

- Discussed success stories of technology/knowledge transfer projects, such as the Natural Gas Pipeline Leak Rate Measurement System and Emissions Quantification Validation process.
- Future OPS program actions include tackling climate change by furthering R&D into the safe and environmentally friendly transportation of emerging fuels by pipeline and advancing equity by conducting further outreach to Minority-Serving Institutions (MSI) through the CAAP program.

2.2.5 Presentation 5: Transport Canada's Transportation of Dangerous Goods (TDG) Research Program

Christopher Blain, Director of Safety Research and Analysis, Transport Canada, presented (**Section 7.1.5**) the following topics:

- Provided an overview of the Transportation of Dangerous Goods (TDG) & the Safety Research and Analysis (SRA) Branch. TDG's mission is to promote public safety in the transportation of dangerous goods by all modes of transport in Canada – rail, road, air, and marine. The TDG program consists of regulatory frameworks & international engagement, SRA, Compliance & Response, and Canadian Transport Emergency Centre (CANUTEC)- Emergency Response. The SRA Branch comprises research & applied analysis, risk management, and data.
- TDG's current research projects include research into lithium-ion batteries and energy storage systems; modeling of an LNG portable tank; and, the investigation into the life extension of intermediate bulk containers (IBC).
- Mr. Blain highlighted some of the TDG's future research plans, which include research into large and small means of dangerous goods containment, root cause analysis, and geospatial analysis of supply chains.

2.3 Q&A and Closing Remarks

The day's activities concluded with an open discussion between forum presenters and participants, focusing on cyber security and reinforced rail tanks for HAZMAT transport. The day concluded with closing remarks from Mr. Andy Leyder, Program Analyst, RD&T Branch.

3 DAY 2: RISK ANALYSIS

3.1 Overview

Day 2 focused on "Risk Analysis" topics and opened with remarks from the following PHMSA official:

- Dr. Britain Bruner, Chief, OHMS RD&T Branch

Following the opening remarks, PHMSA, Volpe, and the U.S. Census Bureau presented HAZMAT rail incidents, commodity flow survey results, and geospatial data and hazardous material incidents.

3.2 Presentations

3.2.1 Presentation 1: Cost of Delay for HAZMAT Rail Incidents

Catherine Taylor, Senior Transportation Economist, Volpe Center, and Ms. Gabriel Rohlck, Senior Economist, PHMSA, presented (**Section 7.2.1)** initial results from the Cost of Delay project. Highlights from the presentation included:

- The project consisted of analyzing freight rail delay costs, passenger delay costs, roadway costs of delay, delay results from track closures, rail traffic, and delays from roadway users.
- The cost of delay depends on several factors, such as if rail lines are closed due to an incident, the duration of the closure, the location of the closure (how much freight rail traffic is impacted), or if passenger rail traffic is impacted, or capacity of the rail line.
- Project analysis estimates the costs incurred by railroads for both waiting and rerouting and assumes the railroad will choose the lowest cost option. For example, using a scenario-based approach, there are 181 randomly selected locations from the U.S. freight rail network. For each scenario, the freight railroads can wait or reroute around the closure.

3.2.2 Presentation 2: Commodity Flow Survey Expanded Hazardous Materials Supplement

Ms. Trina Aime, Program Manager, Economic Reimbursable Surveys Division, U.S. Census Bureau, and Mr. Robert Starin, Chief, Data Risk & Analytics, PHMSA, presented an overview (**Section 7.2.2**) of the Commodity Flow Survey (CFS) and the Hazardous Material Supplement:

- An expanded hazardous materials supplement was requested by PHMSA to conduct an annual survey to provide estimates on the types of packaging used in shipping hazardous materials. No survey exists collecting detailed packaging of hazardous material.

- The CFS is a joint effort by the Bureau of Transportation Statistics (BTS) and the U.S. Census Bureau. It is conducted every 5 years as part of the Economic Census, most recently in 2017 and next in 2022. CFS collects data on the movement of goods within the U.S. and captures the volume of hazmat transported.

- The current plan is to integrate the PHMSA data collection request into the CFS by expanding the hazardous materials data already collected. Additional responses on hazardous materials and packaging types were collected from the CFS supplemental questionnaire.

- The next steps include analyzing data from the hazardous material supplemental, tabulating the estimates and, determining the future of hazmat packaging data collection.

3.2.3 Presentation 3: OHMS Geographic Information System (GIS) Working Group

Members of the PHMSA RD&T branch, including Mr. Andy Leyder, Program Analyst, Ms. Ashley Horton, Accident Investigator, and Mr. Marcus Epps, Team Lead, presented an overview (**Section 7.2.3**) of the GIS Working Group, created to utilize GIS with hazardous material data. The following points provide an overview of the presentation:

- The GIS working group is an internal group of members within OHMS, whose goal is to investigate how to use GIS to map out hazardous material data, such as hazardous material incident data.

- The group presented background information on GIS and the hazardous material incident data as well as the CFS data the group is utilizing for one of its GIS projects.

- The group showcased its initial GIS project, mapping out the CFS of class 3 flammable liquid on highways in California with class 3 highway hazardous material incidents. The objective of this project was to demonstrate the use of PHMSA incident data and commodity flow data to visualize hazmat incidents.

- Additionally, the group discussed how GIS can assist in visualizing other data within PHMSA and other potential projects the group might explore.

3.3 Q&A and Closing Remarks

The attendees expressed a high interest in using GIS as a tool to map out incidents and data. There were several questions about how the GIS working group created the map, their methodology to determine which hazardous material to use, and their process of tabulating the data.

The day's activities concluded with an open discussion between forum presenters and participants, and closing remarks from Ms. Ashley Horton, Accident Investigator, PHMSA.

4 DAY 3: ENERGY PRODUCTS

4.1 Overview

Day 3 focused on “Energy Product” topics and opened with remarks from the following PHMSA officials:

- Dr. Pedro Bueno, Chemist, PHMSA

Opening remarks were followed by three presentations from PHMSA, the Safety Management Services, and the Naval Research Laboratory. Forum presenters focused on the topic of “Energy Products” and highlighted lithium-ion battery research and the default declassification of explosives (thermite).

4.2 Presentations

4.2.1 Presentation 1: Default Classification of Explosives (Thermite)

Mr. Troy Gardner from Safety Management Services presented (**Section 7.3.1**) on the “Energetic Properties of Thermites.” The following points highlight the discussion and presentation:

- Mr. Gardner presented an introduction into what thermites are and their current United Nations (UN) regulations regarding these substances.
- After testing many types of thermites under various UN tests for flammable solids, it was concluded that traditional UN tests are not sufficiently accurate to communicate possible hazards and that some explosive or flammable solids could be shipped as non-hazardous under these tests.
- In conclusion, Mr. Gardner proposed a new classification system and expressed the need for further research to understand the hazards presented by thermites in transport.

4.2.2 Presentation 2: Lithium Battery Air Safety Advisory Committee

Mr. Steve Webb, International Standards Transportation Specialist, PHMSA, provided an update (**Section 7.3.2**) from the PHMSA Lithium Battery Air Safety Advisory Committee:

- Mr. Webb first provided an overview of the international regulatory system and UN Model Regulations for the Transportation of Dangerous Goods.
- The LBC report includes the following recommendations:
    - Enhance reporting system for incidents related to lithium battery and equipment. The goal is to have more information than what is required to provide better reporting.

- Create a process for forensic evaluation and root cause analysis of lithium batteries and equipment involved in an aviation-related incident.
- Define all necessary supply chain data and information relevant to aviation to ensure or improve transportation safety.
- Engage with battery manufacturers and the aviation sector to better define the risk profile of batteries shipped in cargo compartments.

4.2.3 Presentation 3: U.S. Naval Research Laboratory Lithium Ion Battery Research

Dr. Corey Love and Dr. Rachel Carter, Chemistry Division, U.S. Naval Research Laboratory, presented (**Section 7.3.3**) on lithium-ion battery research:

- Dr. Corey and Dr. Carter detailed ways and plans to continue researching new strategies to de-energize damaged and defective lithium-ion batteries.
- Discussed the need for research in novel rechargeable battery chemistries and detailed some preliminary and future work related to the development of sodium-ion batteries.

4.3 Q&A and Closing Remarks

The day's activities concluded with an open discussion between forum presenters and participants, and closing remarks from Andy Leyder, Program Analyst, OHMS RD&T Branch.

5 DAY 4: PACKAGING

5.1 Overview

Day 4 focused on "Packaging" topics and opened with remarks from the following PHMSA officials:

- Mr. Andy Leyder, Program Analyst, OHMS RD&T Branch

Opening remarks were followed by three presentations regarding composite metal foams, PHMSA packaging initiatives, and thermo-mechanical responses of FRP composite jacketing from academic stakeholders from North Carolina State and West Virginia State, and A-P-T Research, Inc.

5.1.1 Presentation 1: Composite Metal Foams for Impact Protection of Hazardous Material Transportation

Dr. Afsaneh Rabiei, Professor of Mechanical and Aerospace Engineering from North Carolina State University, presented (**Section 7.4.17.4.1**) on Composite Metal Foams for Impact Protection of HM Transportation:

- Composite metal foams (CMFs) present a new class of materials that stand to revolutionize the materials industry with countless use cases.
- CMFs offer cost savings and environmental friendliness with structure optimization to meet specific needs and can be made from nearly any metal or alloy.
- Testing shows CMFs have proven capabilities with significantly lower weights than current materials in protection against heat, fire, blast, ballistics, sound, vibration, radiation, and impact.
- Large-scale and mass production development are underway.

5.1.2 Presentation 2: PHMSA Packaging Initiatives Summary

Ms. Melissa Emery, Director of the Safety Engineering and Analysis Center, A-P-T Research, Inc., presented an overview (**Section 7.4.2**) on PHMSA packaging initiatives:

- Reported on the classification and transportation of defective and damaged charge storage devices.
- Discussed the classification and research of the transportation of bio-derived fuel
- Presented on mitigating the risks and consequences associated with hazardous materials package rupture.

5.1.3 Presentation 3: Thermo-Mechanical Responses of FRP Composite Jacketing for Tank Cars Under Impact and Fire

Mr. Andrew Kenney, Graduate Student, West Virginia University, and Dr. Hota GangaRao, Professor and Director of Constructed Facilities Center, West Virginia University, presented (**Section 7.4.3**) on the thermo-mechanical responses of FRP composite jacketing for tank cars under impact and fire:

- Developed and tested multiple configurations of fiber-reinforced plastic manufactured by vacuum infusion.
- Cataloged physical properties were examined for protective features including tension, flex, and impact/puncture resistance to develop an optimal combination of material and components.
- Ongoing works include manufacturing refinement, fire resistance, modeling, and cost-effectiveness.

5.2 Q&A and Closing Remarks

The day's activities concluded with an open discussion with forum attendees and presenters. Highlights from the discussion include the following:

- Dr. Afsaneh Rabiei responded to questions regarding similarities and differences between tank steel cars with thermal insulation and composite metal foams and highlighted the advantage of compressibility presented by the foams absent in tank cars while maintaining the tensile strength.

- Questions were posed surrounding the manufacturing differences in composite metal foams and fiberglass/resin composite, incorporation/implementation, and repair/welding.

- A brief discussion on the topic of hydrogen evolving into a popular alternative fuel.

The RD&T Forum concluded with closing remarks from Mr. William "Bill" Quade, Deputy Associate Administrator for Policy and Programs, OHMS.

6 CONCLUSION

The purpose of the OHMS R&D forum was to inform stakeholders of ongoing projects and solicit feedback on future research topic ideas. Over the four days, industry and government presentations sparked conversation among 364 participants which led to new ideas and considerations for the OHMS research program. Some key takeaways of the forum were to expand OHMS research efforts:

- To develop projects from basic research through applied research

- Explore the intersection of risk analysis and materials research as it applies to climate change and aging infrastructure

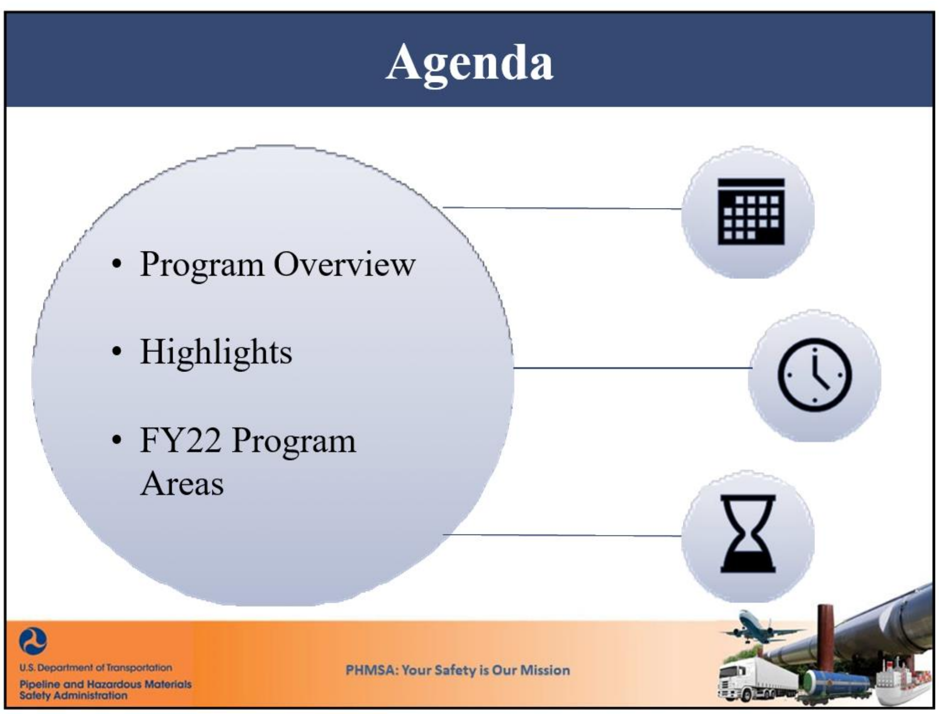
- Develop research on the safe transportation of energy materials.

As OHMS R&D explores these potential research topics, it will continue to seek stakeholder engagement and announce further progress as it occurs.

7 APPENDIX

7.1 Day 1 Presentation Material

7.1.1 RD&T Program Overview Presentation Slides



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OHMS RD&T Team

Yolanda Y. Braxton

Ashley Horton

Andy Leyder

Britain Catlin Bruner, PhD

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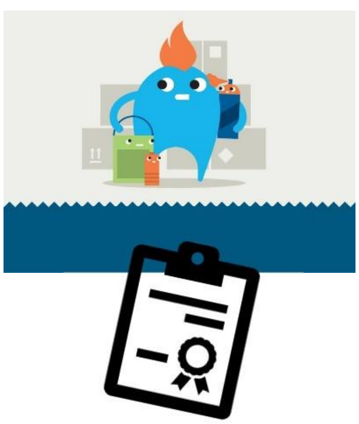
RD&T Objectives



- Provide the research needed to manage the public safety risk associated with hazardous materials transportation.
- Provide the analytical foundation for regulatory and outreach activities.
- Leverage resources to solve multi-modal safety concerns.
- Drive safety innovation and technology transfer.

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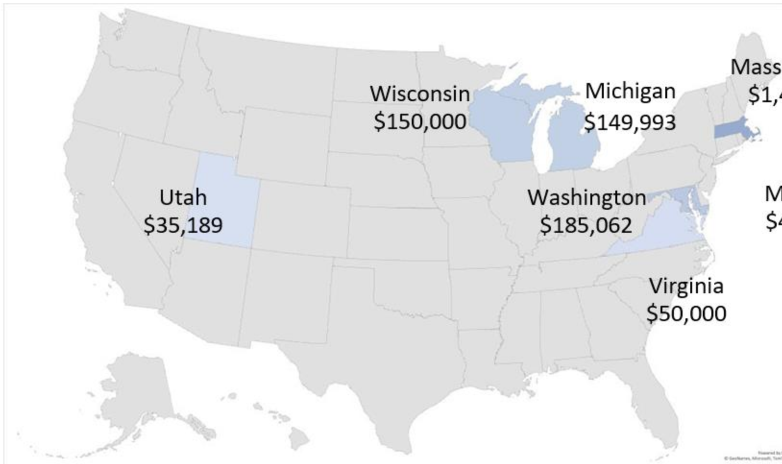
Funding Map FY'21



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Research Solicitations

- Broad Agency Announcement
- Small Business Innovation Research
- Request for Proposals

SAM.GOV

Dr. Britain Bruner

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SBIR
America's Seed Fund

Andrew "Andy" Leyder

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Research Collaborators

Volpe National Transportation Systems Center
National Academy of Science Transportation Research Board

U.S. Naval Research Laboratory
Colleges and Universities

NATIONAL ACADEMY OF SCIENCES

U.S. Department of Transportation Volpe Center

U.S. NAVAL RESEARCH LABORATORY

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2021 Review

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Research Completed

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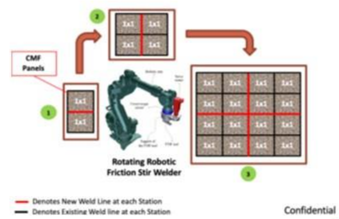

Risk Management

- Research and Regulation of Polymerizing Materials During Transportation.
- Additively Manufactured Metal Foam Rail Tank Car Structures.
- Classification and Transportation of Defective and Damaged Charge Storage Device.
- Classification and Research of the Transportation of Bio-Derived Fuel.

Packaging Integrity

- Mitigating the Risks and Consequences Associated with Hazardous Material Packaging Rupture.

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Research Completed (cont.)

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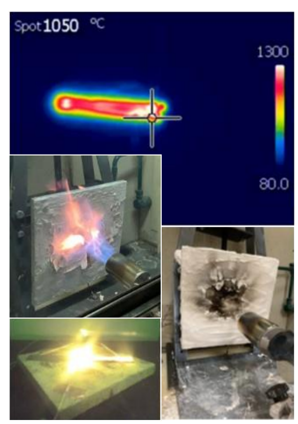

Emerging Technology

- Improved Reaction to Fire Test for Particulate Metals and Method to Evaluate the Efficacy and Limitations of Liquid Suppressant Agent(s) for Metal Fires and Waste Hazard Reduction.
- Development and Testing of New Materials for Improving Thermal Protection Systems to Mitigate Rail Transport Risk of Flammable Liquids.

Technical Analysis to Aid Risk Assessment

- Comprehensive Transportation Risk Model Development.
- Train Energy and Dynamics Simulator.

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Ongoing Research

OHMS FY 2021 Summary

Risk Management

- Composite Metal Foams for Impact Protection of Hazardous Material Transportation.
- Default Classification of Explosives (Thermite).
- Fine Grain Metal Powder Standards for Consumer Pyrotechnics.
- Solidification of NGH for Transportation.
- Thermo-Mechanical Responses of FRP Composite Jacketing for Tank Cars under Impact and Fire.

Packaging Integrity

- Performance Specification of Fiber-Reinforced Plastic Materials for Highway Cargo Tank Packaging.
- Performance Specification of Fiber-Reinforced Plastic Materials for Highway Cargo Tank Packaging Phase II.
- Packaging Technique to Defeat Fires and Explosions due to Lithium-Ion and Related High-Energy-Density Batteries.
- High Strain Rate Rupture and Fragmentation of Aluminum Cylinders.
- FRA's Full-Scale Tank Car Side Impact Testing.

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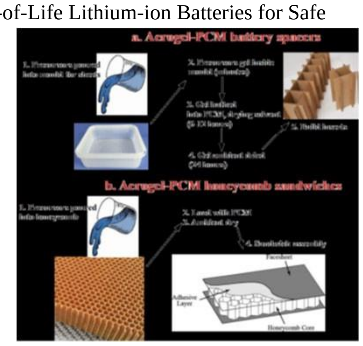
Ongoing Research (cont.)

OHMS FY 2021 Summary

Technical Analysis to Aid Risk Assessment

- Development of Annual Hazmat Packaging and Commodity Flow Data.
- Strategies to De-energize Damaged/Defective and End-of-Life Lithium-ion Batteries for Safe Shipment.
- Nurse Tank Fatigue Life Analysis.
- LNG by Rail.



Emerging Technology

- Honeycomb-Encapsulated Phase Change Materials Composites for Battery Transportation Safety.
- Wabtec Consist Integration with AskRail.
- Sodium Ion Battery Testing.
- Battery Logistics Integrated Safety Systems.
- Active Termination of Lithium-Ion Battery Fires and Thermal Runaway.

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Research, Development and Technology FY 2022 Program Areas

Risk Management and Mitigation	Research will focus on risk reduction strategies designed to lower transport-related injuries and fatalities, increase packaging and operational safety, or improve system reliability.
Packaging Integrity	RD&T research focuses on improving packaging design and integrity.
Emerging Technology	RD&T reserach helps PHMSA to keep pace with the need for packaging designs and regulations to evolve.
Technical Analysis to Aid Risk Assessment	Development of hazardous materials commodity flow analysis, review of incidents and packaging failures for patterns and similarities, and development of inspection and test methods for classification of hazardous materials and for packaging containing hazardous materials.

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Thank You!

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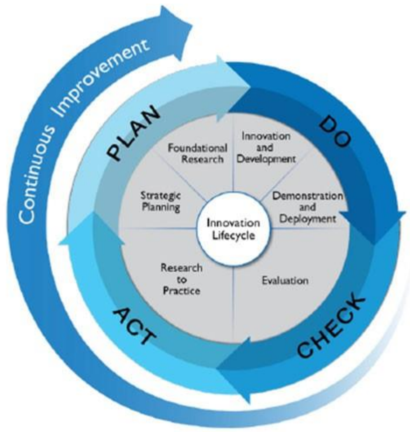
7.1.2 Office of Planning & Analytics Program Overview Presentation Slides



DOT Research and Development Strategic Priorities

Climate Change and Equity

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PHMSA Efforts in GHG Climate Change

Transport safety will always be the mission; however, PHMSA will be promoting the development of innovative global transport safety standards to support alternative and sustainable energy sources, new technologies, and process innovations.

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Research Lifecycle

Research Follows a lifecycle from developing new scientific knowledge to implementation

Researchers may enter this process at various points and exit depending upon research goals and public versus private sector needs

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UNITED STATES
DEPARTMENT OF TRANSPORTATION

Climate Activities by OA and Office

DOT Climate Change Center

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To Protect People and the Environment From the Risks of Hazardous Materials Transportation

4

FHWA Office of Environment and Realty

Resilience

- Planning, Asset Management, Pavements, Coastal and River Hydraulics, Geohazards, Wildfires

Analyzing Greenhouse Gases (GHGs)

- Tools and methods to estimate GHG emissions

Reestablish GHG Performance Measure

- For example, in 2019, we released an Implementation Guide on Nature-Based Solutions for Coastal Highway Resilience.

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FHWA Office of Environment and Realty

Alternative Fuel Corridors, Electric Vehicle Charging, and Renewable Energy

- Round 5 Alternative Fuel Corridor Designations
- Funding Alternative Fuel Infrastructure Mini-Report
- Alternative Use of the Right-of-Way Guidance

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To Protect People and the Environment From the Risks of Hazardous Materials Transportation

6

Federal Motor Carrier Safety Administration Government Partners: EPA, DOE, NHTSA

By 2035, mandate that all newly-manufactured Commercial Motor Vehicless must be zero emissions
By 2040, mandate the all CMVs in a motor carrier's fleet be zero emissions in order to receive a USDOT number

New trucks have very low emissions, as mandated by the EPA, but there are still some dangerous emissions discharged into the atmosphere.

- From 2007 to 2017, NOx emissions dropped by more than 40 percent
- While current idling times are 30% to 40% of engine operating time

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Federal Motor Carrier Safety Administration Government Partners: EPA, DOE, NHTSA

Public Private Partnership (PPP) Program to Facilitate Installation of Electric Vehicle Charging Stations for CMVs at Truck Rest Stops.

Facilitating the operation of electric CMVs could significantly reduce overall vehicle emissions

- Studies indicate roughly 80% of highway freight travels 250 miles or less

Although less than 1% of fleet vehicles today are electric, this number is expected to grow to 12% by 2030

Government Partners: EPA, DOE, FHWA

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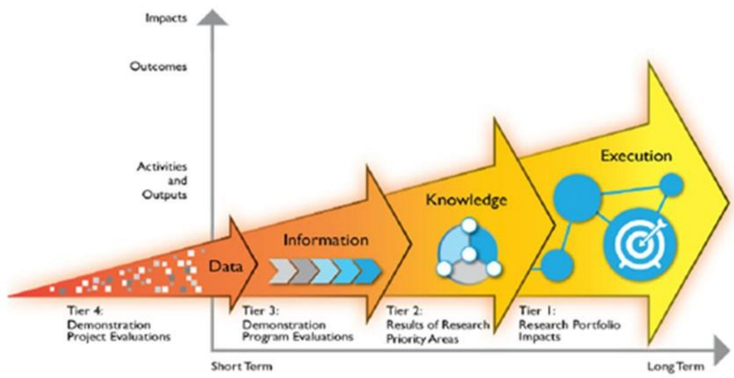
FTA: Research Implementation



Source: FTA Nested Research Framework April 2018FTA Internal Report No. 002

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FTA: Research Implementation

FTA's Transit Greenhouse Gas Emissions Estimator Tool
TCRP Research Report: *An Update on Public Transportation's Impacts onGreenhouse Gas Emissions (2021)*
Bus Efficiency Enhancements Research and Demonstration Programs: Thermoelectric Generation; Paratransit Vehicle Accessory Electrification; Reduced Engine Idle Load System; Hybrid Beltless Alternator Retrofit
FTA's discretionary grant programs (e.g., Low or No Emissions)
FTA C 5010.1E: requires recipient to complete an energy assessment prior to approving grant application for construction, reconstruction, or modification of buildings

- Energy conservation elements (including pursuit of LEED certification) can be included in design and construction costs eligible for FTA funds

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Federal Aviation Administration

Area	Actions
Research and Development	• Launch CLEEN III Program – Announce Awards – May 2021 • ASCENT Center of Excellence – Spring Meeting – April 2021 • Fund new climate-related projects
Climate Action Plan	• Develop aviation climate action plan to detail U.S. actions to achieve aviation emissions reductions consistent with a pathway to economy-wide net zero emissions. Including: Technology, SAF, Operations, Policy, International
Regulatory Development	• Airplane CO2 Standard Notice of Proposed Rulemaking – sent to OST by 9/30/21 • CORSIA Implementation (includes both offsetting criteria and fuels sustainability criteria) • Particulate Matter Standard – Coordinate with EPA and implement ICAO standard through rulemaking
International	• ICAO Council – Climate deliberations – May/June • ICAO Committee on Aviation Environmental Protection – Annual Steering Group Meeting – July 2021 • Bilateral climate engagement
Resiliency / Adaptation	• Evaluate and mitigate the risks of sea level rise and other impacts of climate change on FAA infrastructure and our ability to safely operate the NAS.

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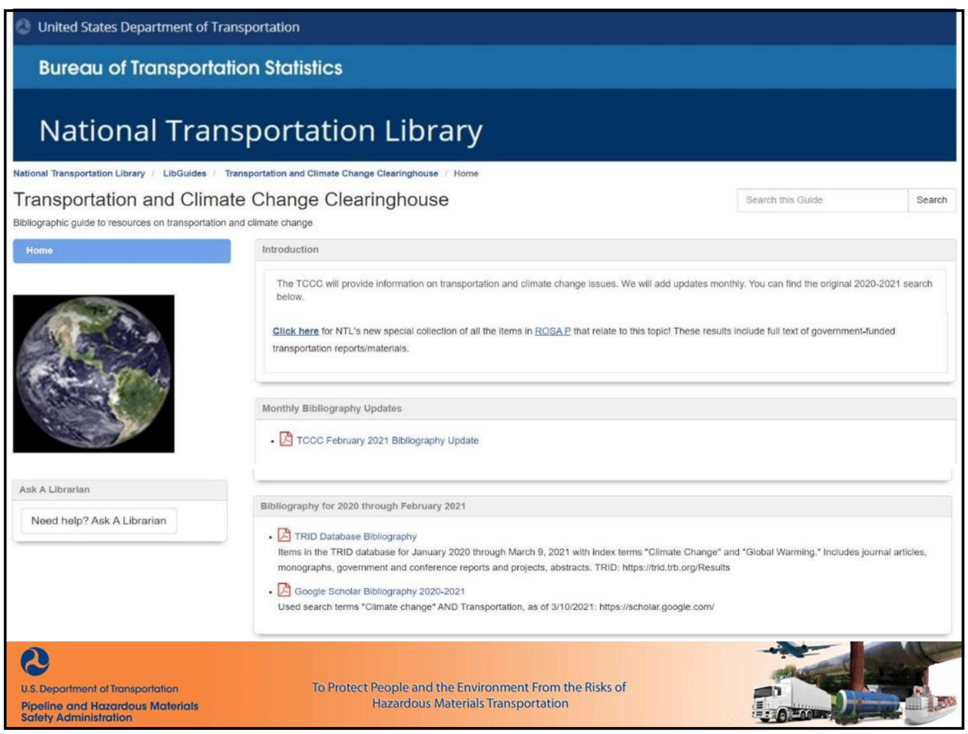

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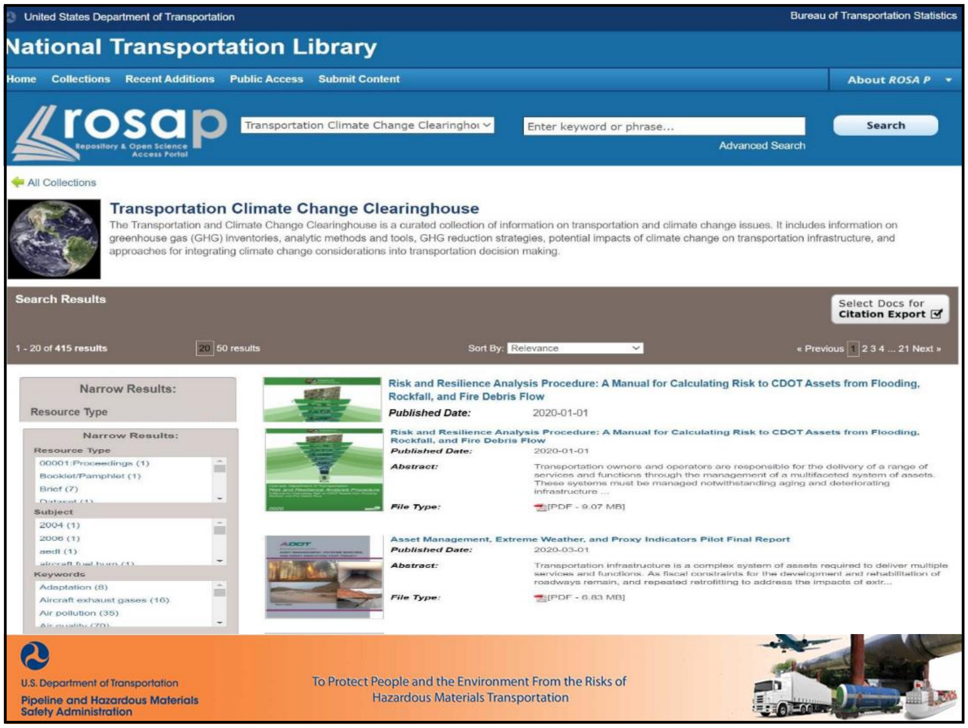

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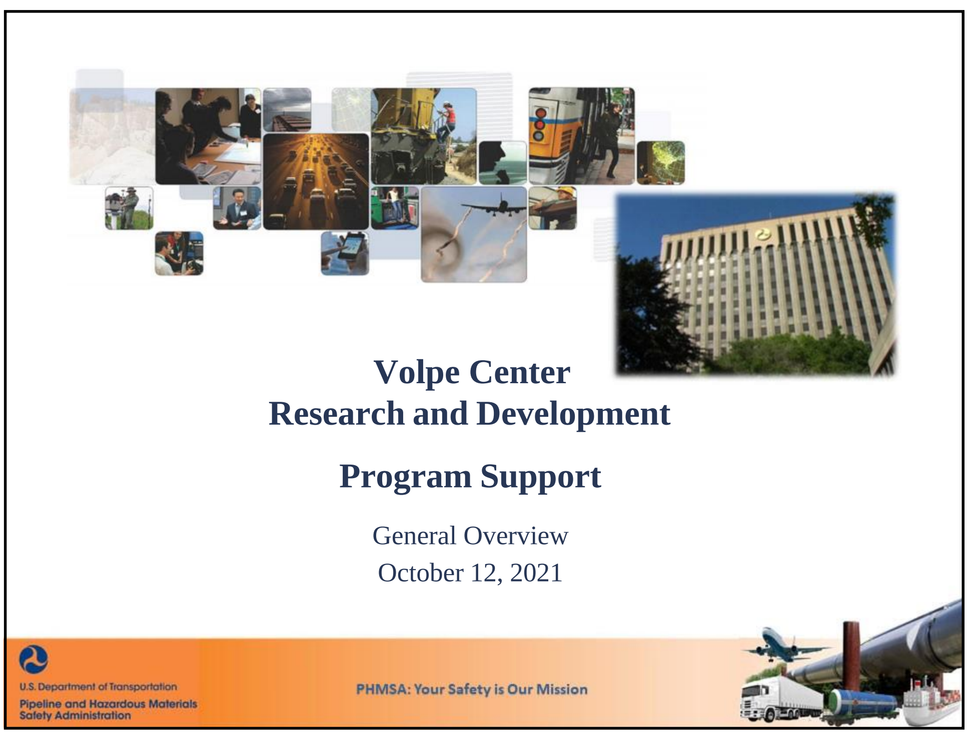
7.1.3 Volpe National Transportation System Center Overview Presentation Slides



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Agenda

- Volpe Center Overview
- R&D Program Support
  - General Support
  - Key Active Projects

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What is the Volpe National Transportation Systems Center?

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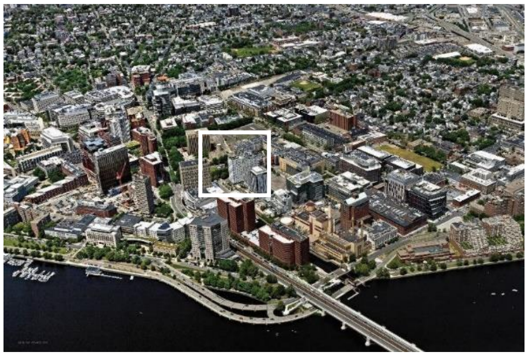
A Catalyst for Innovation in Cambridge, MA

Our Mission: Improve the nation's transportation system by anticipating emerging issues and advancing technical, operational, and institutional innovations for the public good.



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Volpe's Role in the U.S. DOT

We provide **technical expertise** and develop solutions to complex transportation challenges in support of U.S. DOT, other federal agencies, and external organizations.

Our **rapid-response capability** is critical to OST, the operating administrations, and other federal agencies.

A federal agency, we perform **inherently governmental** functions on behalf of U.S. DOT and others and are committed to **public service.**

Our **institutional memory** provides the U.S. DOT with a **historical perspective** that cannot be found

We **anticipate emerging and future transportation issues** and inform decision-

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Top Capabilities

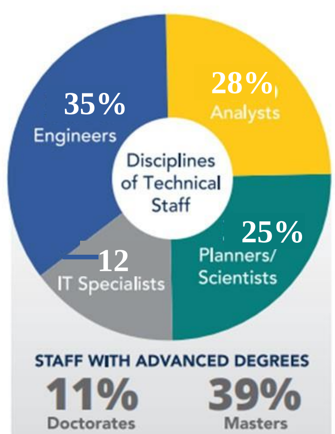
- Safety and Security Assessments
- Engineering and Technology Deployment to Enhance Transportation
- Human Factors, including Human-Automation Interaction
- Applied Data Science
- Environmental Analysis, Science, and Engineering
- Impartial Investigations and Program Evaluations
- Economic and Policy Analysis
- Systems and Infrastructure Modernization and Optimization
- Knowledge Transfer and Capacity Building

6

Our Workforce

- We are home to a federal, multimodal, multidisciplinary technical workforce and who possesses a deep knowledge of government operations.
- ~580 federal staff members.
- As one of Cambridge's Top 20 employers, the Volpe Center supplements its federal team with

Learn more about Volpe at volpe.dot.gov



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U.S. DOT's SBIR Program (SBIR)

SBIR

- Volpe administers the Small Business Innovative Research (SBIR) program on behalf of the U.S. DOT, working with funding operating administrations to award contracts to domestic small businesses to pursue research on and develop innovative solutions to our nation's transportation challenges.

- U.S DOT is one of 11 federal agencies that participates in the SBIR program, with involvement from eight other operating administrations including PHMSA.

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Volpe's Support to PHMSA's R&D Program

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Hazardous Materials Safety R&D Program

- Volpe has a general service type IAA to provide holistic program level support, on an as needed basis, to aid in the implementation of the R&D program. Providing:
  - Program management and subject matter expertise,
  - Research implementation and analysis, and
  - Stakeholder outreach and R&D coordination support.

- Separate, IAAs are established for Volpe to conduct individual specific research projects in support of PHMSA's R&D program.

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Program Level Support

- **R&D Program Management and SME Support**
  Volpe provides program management and subject matter expert (SME) support to assist in identifying, designing, developing, and managing research projects to aid in the identification and mitigation of risks associated with the transportation of HM and to better understand the contributing risk factors.

- **Research Implementation and Analysis**
  Volpe assists PHMSA in conducting research and analytical activities to aid in identifying, researching and mitigating existing and emerging HM transportation risks, packaging, incidents, and transport scenarios and operations.

- **Stakeholder Outreach and R&D Coordination**
  Volpe assists PHMSA in developing and implementing internal and external stakeholder communication, outreach, and research coordination efforts.

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Nurse Tank Fatigue Life Analysis (Phase 1)

- The overall goal of the project is to use simulation and modeling technologies to analyze the fatigue life of nurse tanks currently in operation, in order to understan the service life of those nurse tanks.
- The findings will be used to determine if requirements dictated by the hazardous materials regulations provide an equivalent level of safety as the requirements for other cargo tanks.

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Nurse Tank Fatigue Life Analysis (Phase 1)

- Under this first phase, Volpe is conducting upfront investigative research to better understand the:
  1. Variety of manufactured nurse tank designs;
  2. Current fleet of operating nurse tanks;
  3. Nurse Tank service environments, operations, failures, testing and inspection practices and observations, stakeholder concerns, industry practices, etc.; and
  4. To determine the approach and requirements for defining the larger modeling and analytical effort to be conducted under a future phase.
- Investigative research includes conducting a focused literature review, limited upfront data research, and outreach activities.
- The outcome of Phase 1 will be a project plan that will provide the roadmap and define the requirements, activities, timeline, and refined budget for subsequent phases.

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FRP Materials for Highway Cargo Tanks

Objective: to perform experimental testing and develop a finite element analysis (FEA) framework to evaluate the performance of cargo tank motor vehicles (or CTMVs) made with fiber-reinforced plastic (or FRP) materials. The goal being to provide performance dataand technical parameters for PHMSA's consideration in a possible rulemaking on FRP CTMVs.

<u>The study includes</u>:

- Obtaining varying specified FRP specimens from multiple commercial FRP CTMVmanufacturers,
- Conducting material and component level testing on the FRP specimens,
- Developing, calibrating and validating material and component level models using the material and component level test data, and
- Developing full-scale FE models of FRP CTMVs and conducting full-scalesimulations to evaluate their performance.

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Cost of Delay for HAZMAT Rail Incidents

Objective: to evaluate the costs of delay in freight transportation incidents by rail and develop methods to estimate and monetize delay costs specific to rail transportation incidents involving hazardous materials releases.

- Phase 1: entails conducting a literature and data review and developing the preliminary research plan for Phase 2.
- Phase 2, entails conducting the delay simulation modeling and cost of delay modeling, an external stakeholder review, addressing stakeholder feedback, and finalizing models and project report.

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7.1.4 Office of Pipeline Safety Program Overview Presentation Slides

1

Pipeline Safety Research Program Mission

To sponsor research and development projects focused on providing **near-term solutions** for the Nation's pipeline transportation system that will improve **safety**, reduce **environmental impact**, and enhance **reliability**.

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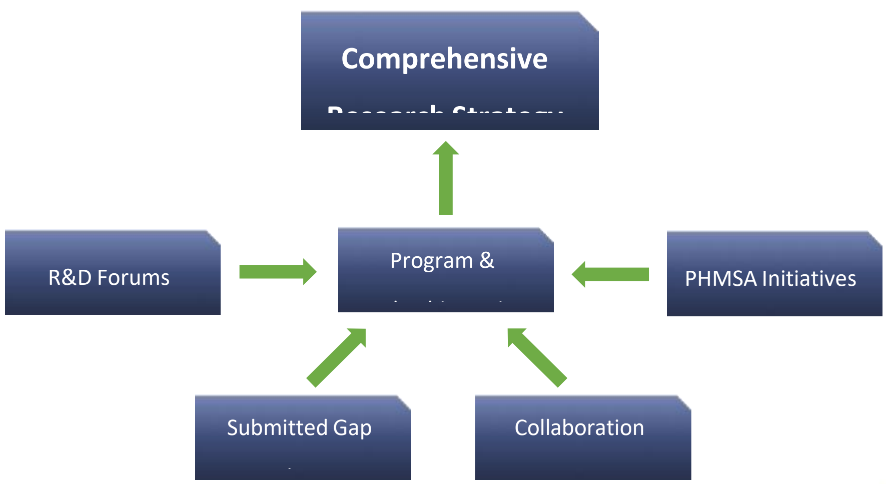
Research Program Strategy Development



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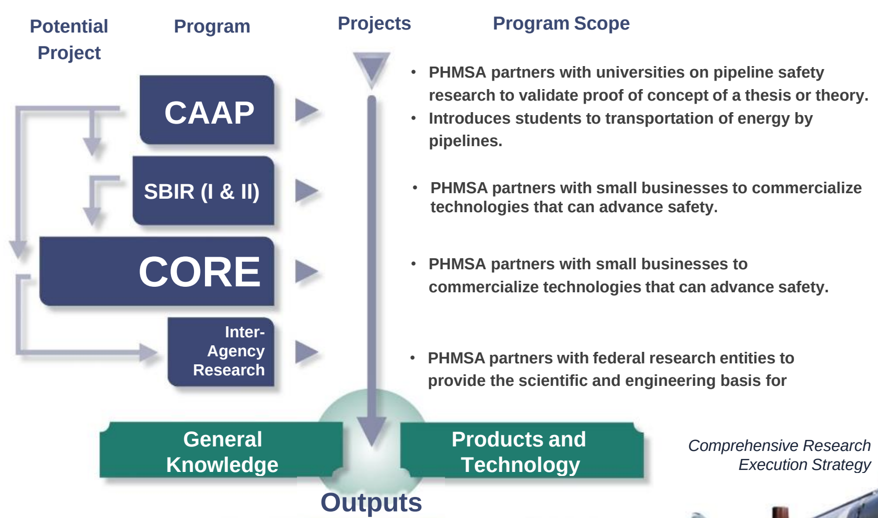
Research & Development Program



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R&D Focus Areas

Number	Focus Area
1	Liquefied Natural Gas (LNG) Safety
2	Underground Natural Gas Storage (UNGS) Safety
3	Pipeline Anomaly Detection/Characterization
4	Pipeline Leak Detection
5	Pipeline Threat Prevention
6	Repair/Rehabilitation
7	Design & Materials
8	Alternative Fuels Research to Address Climate Change

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Program Performance

	Program Total
Total R&D projects funded since 2002	363
Total R&D investment through PHMSA:	$155 M
Technology projects funded:	112
Commercialized technologies:	33
Active R&D projects:	66
CAAP Student Involvement:	343

Data From:
https://www.phmsa.dot.gov/research-and-development/pipeline/about-pipeline-research-development
https://primis.phmsa.dot.gov/matrix/

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Example Success Story
Technology/Knowledge Transfer

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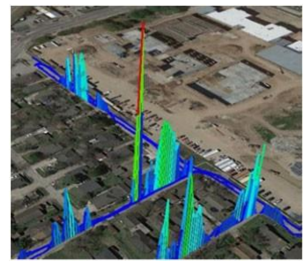
Technology Transfer Project #1

Natural Gas Pipeline Leak Rate Measurement System	
Researcher:	Physical Sciences, Inc.
PHMSA Costs:	$226,794
Main Objective:	To develop survey technologies and methodologies to locate and quantify fluxes of non-hazardous natural gas leaks.
Net Improvement:	Commercialized by Heath Consultants, Inc. in December 2018. The research improved the methane/ethane analyzer, and proprietary leak detection software presenting a real-time geospatial maps of multiple gas concentrations. MobileGuard is a laser-based sensor with sensitivity and precision more than 3,000 times greater than legacy methods. This enables identification of leaks several hundred feet away from the source.



Pictures courtesy of Heath Consultants, Inc.

https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=650

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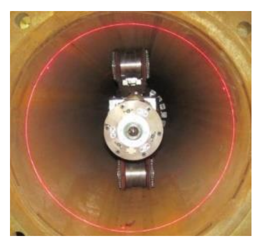
Technology Transfer Project #2

Development, Field Testing and Commercialization of a Crack and Mechanical Damage Sensor for Unpiggable Natural Gas Transmission Pipelines	
Researcher:	Northeast Gas Association
PHMSA Costs:	$840,396
Main Objective:	To develop a combined mechanical and crack sensor for use on robotic inspections of unpiggable natural gas pipelines.
Net Improvement:	The research supported the launch of the Laser Deformation Sensor (LDS) on the Pipetel Explorer line of robotic inspection tools. The LDS is a laser-based sensor that allows the identification of any mechanical damage or ovality issues in a challenging to inspect or unpiggable natural gas transmission pipeline.



Pictures courtesy of Northeast Gas Association

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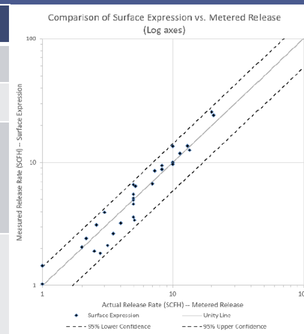
Knowledge Transfer Project #1

Emissions Quantification Validation Process	
Researcher:	Northeast Gas Association
PHMSA Costs:	$144,670
Main Objective:	To identify, apply and test a methodology or methodologies that validate quantified methane emissions rate measurements in gas distribution systems.
Net Improvement:	After project completion in March 2019, Northeast Gas Association pipeline operator member companies continued to use this developed methodology successfully. In 2021, Northeast Gas Association and member companies were working with the American Society for Testing and Materials Committee on Air Quality (D.22) to develop a nationally recognized standard methodology based on this research.



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Pictures courtesy of Northeast Gas Association.

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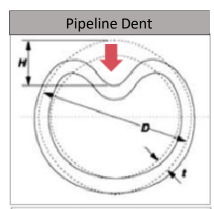
Knowledge Transfer Project #2

American Petroleum Institute Recommended Practice 1183 – *Assessment and Management of Dents in Pipelines, 1st Edition*	
Researcher:	Gas Technology Institute
PHMSA Costs:	$4,531,000
Main Objective:	Various in mechanical damage
Net Improvement:	Portions of research knowledge resulting from these 5 projects were utilized by the API in the development of Recommended Practice 1183. 1. Mechanical Damage at Welds 2. Structural Significance of Mechanical Damage 3. Dent Fatigue Life Assessment - Development of Tools for Assessing the Severity and Life of Dent Features 4. Consolidated Project Full Scale Testing of Interactive Features for Improved Models 5. Improving Models to Consider Complex Loadings, Operational Considerations, and Interactive Threats



https://primis.phmsa.dot.gov/matrix/

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Active Research

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Current R&D Focus Areas

	Program Total	
Total Active R&D Projects	66	
Total R&D investment through PHMSA:	$35.7 M	
Active Subject Areas of Research	**Projects**	
LNG Safety	4	$3.1 M
Pipeline Anomaly Detection/Characterization	17	$9.8 M
Pipeline Leak Detection	7	$2.4 M
Pipeline Threat Prevention	31	$17.5 M
Repair/Rehabilitation	1	$300 K
Design & Materials	6	$2.6 M

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Major R&D Funding in FY 2021

CORE	CAAP
• PHMSA solicited for the Research Award 7 in March of 2021	• PHMSA solicited for the 2021 CAAP Program in January of 2021
• 24 proposals from 17 applicants	• 20 proposals from 16 universities
• Technical merit review completed	• Technical merit review completed
• PHMSA is seeking approvals for making awards	• PHMSA is seeking approvals for making awards
• Awarded projects in these areas on September 30, 2021:	• Awarded projects in these areas on September 30, 2021:
1. Threat Prevention	1. Remote Monitoring Technology
2. UNGS	2. Artificial Intelligence-Automation Solutions
3. LNG	
4. Materials	

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R&D Links

- R&D Program Website -
- https://www.phmsa.dot.gov/research-and-development/phmsa-research-and-development
- R&D program awards and various research topics - https://primis.phmsa.dot.gov/matrix/
- Submit a research gap suggestion - https://primis.phmsa.dot.gov/rd/gapsuggestions.htm
- R&D workshops, forums, & briefings - https://primis.phmsa.dot.gov/rd/workshops.htm

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Future R&D

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Future R&D Program Actions

- Tackle climate change by furthering R&D into the safe and environmentally friendly transportation of emerging fuels by pipeline
- Advance equity by conducting further outreach to Minority-Servicing Institutions on the CAAP program
- PHMSA will be hosting a virtual R&D forum on Nov 30-Dec 2, 2021 to gather stakeholder input

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7.1.5 Transport Canada, Transport Dangerous Goods Program Overview Presentation Slides

1

OUTLINE

- Overview of TDG & the Safety Research and Analysis (SRA) Branch
- Current research
- Future research plans

2

TDG – MANDATE & ROLE

Promoting public safety in the transportation of dangerous goods by all modes of transport in Canada – rail, road, air, and marine

- Promoting safety, and anticipating and responding to evolving TDG issues, domestically and globally.
- Maintaining a robust TDG regulatory and oversight regime that supports public safety, economic growth and innovation.
- Ensuring risk-based TDG enforcement that is consistent and effective, throughout the country.

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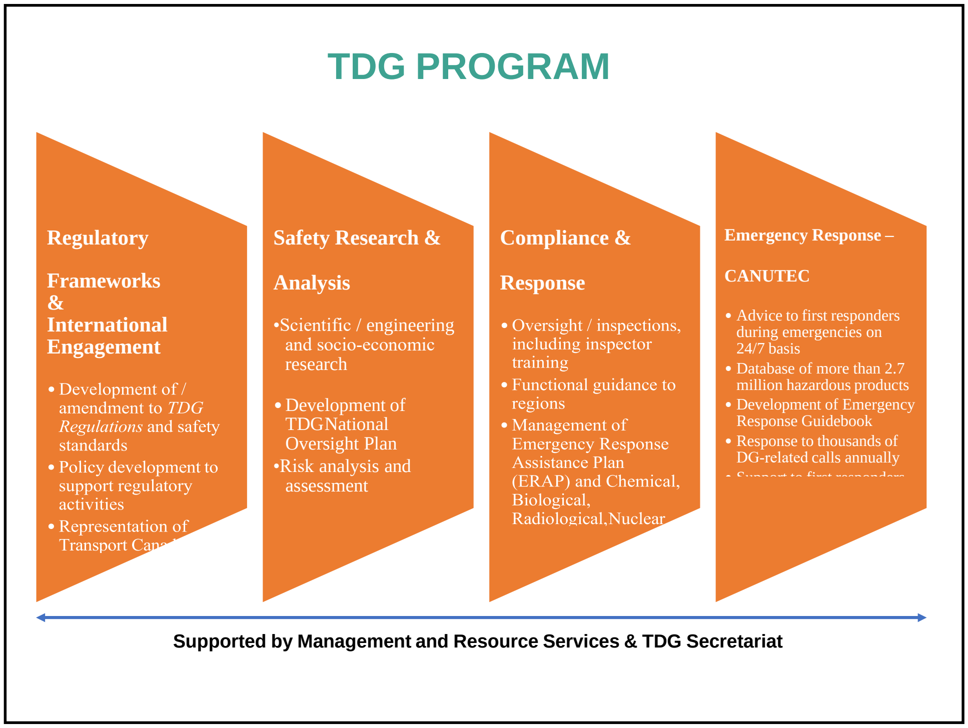
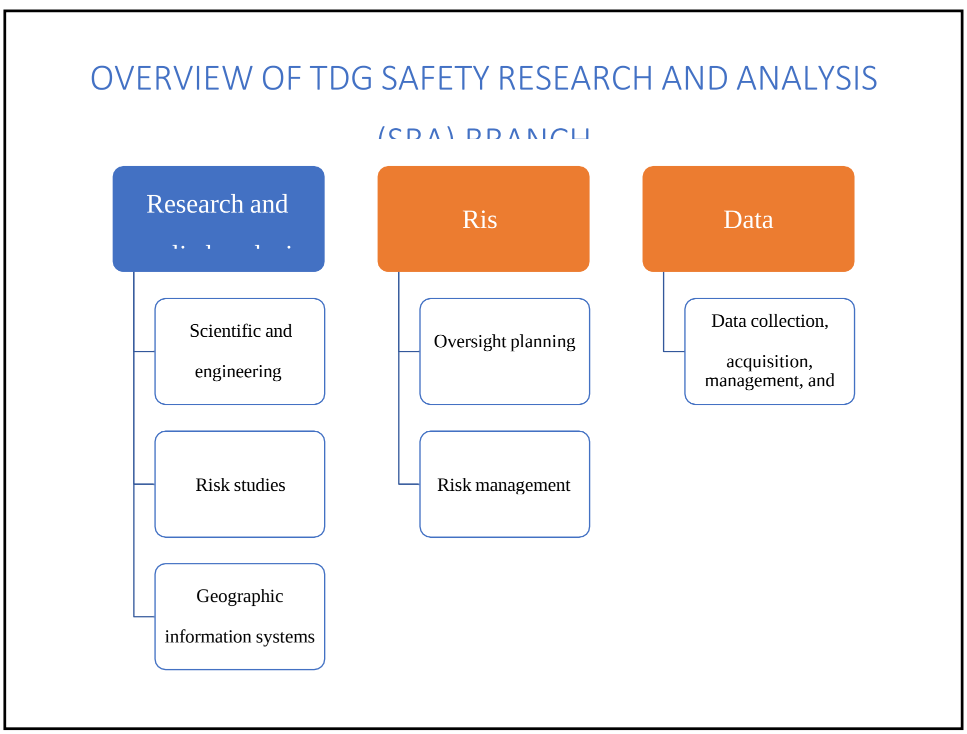

TDG PROGRAM
Regulatory
Frameworks
&
International
Engagement
• Development of / amendment to *TDG Regulations* and safety standards
• Policy development to support regulatory activities
• Representation of Transport
Safety Research &
Analysis
•Scientific / engineering and socio-economic research
• Development of TDGNational Oversight Plan
•Risk analysis and assessment
Compliance &
Response
• Oversight / inspections, including inspector training
• Functional guidance to regions
• Management of Emergency Response Assistance Plan (ERAP) and Chemical, Biological, Radiological,Nuclear
Emergency Response –
CANUTEC
• Advice to first responders during emergencies on 24/7 basis
• Database of more than 2.7 million hazardous products
• Development of Emergency Response Guidebook
• Response to thousands of DG-related calls annually
Supported by Management and Resource Services & TDG Secretariat

4


OVERVIEW OF TDG SAFETY RESEARCH AND ANALYSIS
Research and
Ris
Data
Scientific and engineering
Risk studies
Geographic information systems
Oversight planning
Risk management
Data collection, acquisition, management, and

5

Christopher Director, Safety Research and

Monica Blaney Chief, Data Governance and Geographic Information Systems

Barbara Di BaccoAmy Park Chief, Scientific Research

Carolyn Chief, Research Development, Promotion, and Coordination

6

RESEARCH IN *TDG ACT*

- **Technical research and publication**

  25 The Minister may

  (a) conduct, **alone or in cooperation with any government, agency, body or person**, whether**Canadian or not**, programs of **technical research and investigation** into the development and improvement of safety marks, safety requirements, safety standards and regulations under this Act and coordinate the programs with similar programs undertaken in Canada; and

  (b) have **information** relating to the programs or their **results published and distributed** in a form and manner that are most useful to the public, the Government of Canada and the governments of the provinces.

- **Court order**

  34 (1) Where **a person is convicted of an offence**, **the court may make an order** having any or all ofthe following effects: …

  (d) requiring the person to conduct programs of technical research and investigation into the development and improvement of safety marks, safety requirements and safety standards, **or to pay an amount** in accordance with the regulations **to be used to conduct the research**.

7

Current research

8

CURRENT RESEARCH

Scientific and engineering research

Lithium batteries and energy storage systems:

- Evaluation and analysis of the **hazards posed by common replacement lithium batteries** in transport (*in collaboration with Underwriters Laboratories of CanadaInc. and National Research Council Canada (NRC)*)
- **SAE G-27 Lithium Battery Packaging Performance Standard** – validation testing and round robin testing
- Development of a **smart package for lithium battery**transportation that indicates a warning about an issue inside the package
- Hazard assessment of **energy storage systems** (ESS)being transported **in enclosed vessels** for marine transport

Image source: *Original image from lab testing*

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CURRENT RESEARCH

Scientific and engineering research (cont'd)

Rail:

- **TC-117R tank car derailment** impact study
- Validation of **marshalling** requirements for **dangerous goods cars in a train** – modelling of in-train forces
- Modelling of a **liquefied natural gas (LNG) portable tank** to assess

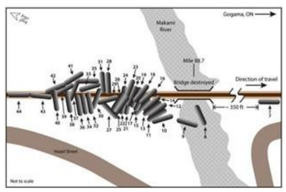

Image source: Transportation Safety Board, incident report TSB R15H0021

Image source: Friedman Research Corporation

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CURRENT RESEARCH

Scientific and engineering research (cont'd)

Other means of containment:

- **Intermediate bulk container (IBC)extension of life** project
- Re-evaluation of **acoustic emission (AE)**data **for composite cylinder requalification**

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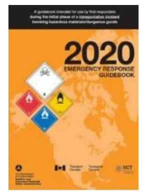
CURRENT RESEARCH

Scientific and engineering research (cont'd)

Emergency response:



- Validation of recommended **emergency actions for liquefied natural gas** (LNG) in the Emergency Response Guidebook (ERG)
- Comprehensive review of the **criteria and thresholds for emergency response assistanceplans** (ERAPs) in the *TDG Regulations*

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CURRENT RESEARCH

Scientific and engineering research (cont'd)

Completed projects with reports to be published this Fall and Winter:

- *Detailed analysis of **crude oil pool fire** data*
- *Validation of numerical fire modeling of **crude oil spills***
- *Modelling the heat transfer, lading response, and pressure relief of **crude oil rail tank cars in a fire***
- ***Tank car fire failure** assessment using combined models*
- *Evaluation of current **tank car TC128B steel weld performance** (high and lowtemperature testing)*
- *Finite element analysis of **tank car hard coupling***
- *Validation of **marshalling** requirements for **dangerous goods cars in a train** (literature review and incident data analysis)*
- *Non-destructive testing feasibility study for **alternating field current measurement** (ACFM) in **rail tank car inspection***
- *Jack Rabbit II chamber study – controlled **environment reactivity** test program*

Abstracts and report summaries will be posted at:

https://tc.canada.ca/en/dangerous-goods/transportation-dangerous-goods-publications

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CURRENT RESEARCH

Risk studies

- Analysis of **rail-based non-accidental releases** (NARs)
- **Social media data mining** project
- Research on the risk factors related to **transporting dangerous goods over bridges**
- Evaluation of any increased risks resulting from greater amounts of **hydrogen** being transported to hydrogen-vehicle fuelling stations
- Development of a **geographic-information-system (GIS) based risk assessment** methodology for the transport of dangerous goods by road

Source: TDG website

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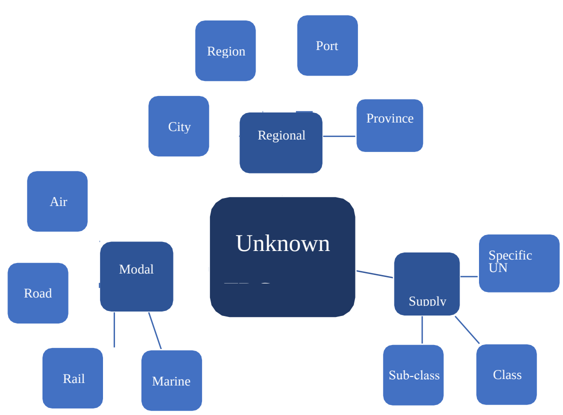
CURRENT RESEARCH

GIS studies



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CURRENT RESEARCH

GIS studies (cont'd)

- Two-part supply chain analysis of **Class 6.2 infectious substances anddangerous goods related to COVID-19 pandemic**
- Logistic analysis of all **dangerous goods waste**
- Continue to concentrate on **road movements of dangerous goods**, in collaboration with provinces and territories
- Deep data dive using **artificial intelligence** (AI) techniques **to identify placarded trucks** moving in an Ontario region that has significant logisticsactivity of dangerous goods
- Further partnerships with U.S. DOT PHMSA on specific **border crossings**

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Future research plans

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FUTURE RESEARCH PLANS

Scientific and engineering research

Lithium batteries:

- Contribution to the development of and testing for revised UN **classification criteria for lithium batteries** *
- Analysis of the reasons for regulatory **non-compliance in the transport oflithium batteries**
- Safety analysis of **stranded energy in a lithium-ion battery** pack

** Possibly depending on external parties*

This list of pending projects should be reviewed periodically to confirm or re-assess priorities and continued validity.

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FUTURE RESEARCH PLANS

Scientific and engineering research (cont'd)

Large means of containment:

- Development of requirements for a new standard for **flexible fabric tanks for the aerial transport of fuels**
- Evaluation of American Society of Mechanical Engineers (**ASME**) ***Boiler and PressureVessel Code*** **Section XII** requirements for the manufacture and continued service of highway tanks in Canada
- Validation of upcoming new United Nations (UN) requirements for **fibre-reinforced plastic(FRP) portable tanks**, to consider for adoption in North America *
- Evaluating the applicability of damage assessment criteria for pressure tank cars towards **damage assessment for general-service tank cars**
- Collecting data on **steels used for the manufacture of highway tanks**, for **damageassessment** purposes
- Using **fibre-optic sensing for the qualification of new materials and new designs** formeans of containment

** Possibly depending on external parties*

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FUTURE RESEARCH PLANS

Scientific and engineering research (cont'd)

Small means of containment:

- Analysis of and potential uses for shredded waste from **used explosives packagings**
- Determining the **status of the hydrogen storage system after a vehicle fire**,so that the damaged hydrogen storage system can be transported safely using the appropriate post-fire handling measures
- Evaluation of **CG-7 pressure-relief devices for cylinders**, to consider the possible extension of the requirement for replacement/re-test within 10years of the date of manufacture *

** Possibly depending on external parties*

This list of pending projects should be reviewed periodically to confirm or re-assess priorities

20

FUTURE RESEARCH PLANS

Scientific and engineering research (cont'd)

Emergency response:

- Review of the **recommended distances for boiling-liquid expanding-vapour explosions** (BLEVEs) in the Emergency Response Guidebook (ERG)
- Review of **penetration failures in past vent-and-burn** procedures, andconsideration of possible solutions
- Consideration of methods for **remote placement of shaped charges in the vent-and-burn** technique

This list of pending projects should be reviewed periodically to confirm or re-assess priorities and continued validity.

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FUTURE RESEARCH PLANS

Scientific and engineering research (cont'd)

Analytics and root-cause analysis:

- Analysis of considerations for the development of TankFax, a **database of vehicle histories of highway tanks**, in Canada
- Consideration of **human factors in TDG training requirements**

This list of pending projects should be reviewed periodically to confirm or re-assess priorities and continued validity.

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FUTURE RESEARCH PLANS

Risk and GIS studies

Source: https://tc.canada.ca/en/campaigns/national-drone-safety-awareness-day-november-13

Risk:

- Assessing and analyzing the current risk profile of **remotely piloted aircraft systems** (RPAS)

GIS:

- Continue with **supply chain analyses** and **regional/modal analyses**

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7.2 Day 2 Presentation Material

7.2.1 Cost of Delay from HAZMAT Rail Incidents Presentation Slides

Cost of Delay for HAZMAT Rail Incidents

Initial Results

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Research Team

- PHMSA
  - Gabriela Rohlck
  - Mark Johnson
  - Jonathan Lesko
  - Andrew Leyder
- FRA
  - Mark Maday
  - Marc Fuller
  - Ryan Arbuckle
- Volpe National Transportation Systems Center
  - Economists
    - Catherine Taylor, PI
    - Matthew Keen
    - Claire Roycroft
    - Sarah Plotnick
    - David Hyde
  - GIS specialists
    - Gary Baker
    - Peter Wilke
  - Environmental Modelers
    - Andrew Eilbert

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Research Objective

Costs estimated in this report	Costs **not** estimated in this report
• Delay costs resulting from rail network users related to waiting and rerouting • freight • passenger • Delay costs resulting from roadway users (vehicular traffic at and around site of incident)	• Fatalities/injuries • Property damage • Emergency services • Environmental damage • HAZMAT release • HAZMAT cleanup • Evacuation (lodging, meals)

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Project Milestones

- Phase 1:
  - Completed Spring 2020: Literature Review and Work Plan
- Phase 2:
  - Summer 2020 – Spring 2021: Develop initial results
  - Summer 2021: Gather stakeholder feedback
  - Current: Finalize results based on stakeholder feedback

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Model Framework

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Cost Model

- Delay results from track closures
- Rail traffic (freight and passenger) needs to either wait until an incident is cleared or reroute around an incident
- Delay may also be experienced by roadway users
  - blocked grade-crossing, debris on roadway, evacuation, roadway used to stage equipment for the response effort

Freight Rail + Passenger Rail + Roadway Cost of = Total Cost

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Cost of Delay Depends on Several Factors

- Whether there is a rail line closure due to the incident
- The duration of the closure
- Whether there is a roadway closure due to the incident
- The location of the closure, which determines:
  - How much freight rail traffic is impacted,
  - How much, if any, passenger rail traffic is impacted,
  - The capacity of the rail line which determines how quickly the impacted traffic can resume normal operations after a closure ends, and
  - The characteristics of alternate rail routes around the site of the closure.
- **Accident releases (ARs) and non-accident releases (NARs) are analyzed separately**

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Scenario-Based Approach

- Scenarios are a specified network location and closure duration
  - 181 randomly selected locations from the US freight rail network
- For each scenario, the freight railroads can wait or reroute around the closure
- This analysis estimates the costs incurred by railroads for both waiting and rerouting, and assumes the railroad will choose the lowest cost option

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Social Costs versus Business Costs

	Business Costs of Delay	Social Costs of Delay
Freight	• Crew time • Equipment • Fuel (including taxes) • Time Value of Freight (proxy forpenalties charged by shippers)	• Crew time • Equipment • Fuel (not including taxes) • Emissions • Time Value of Freight
Passenger	N/A	• Crew time • Equipment • Fuel (not including taxes) • Emissions • Passenger value of time (VOT) • Cost of a “Bus Bridge”
Roadway	N/A	• Passenger and Truck DriverVOT • Fuel (not including taxes) • Emissions

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Freight Cost of Delay

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Characteristics of Incidents

- 10 years of Form 5800.1 data: 2010 through 2019

Incident Type	Number of Incidents	Number of Closures	Percent with Closures
NAR	5,888	92	1.6%
AR	268	109	41%

- Durations
  - NAR – 4-hour median closure duration
  - AR – not clear how much of closure is due to the incident and how much due to presence of HAZMAT. No information on closure durations for incidents without HAZMAT.
  - For ARs, we assume HAZMAT incidents that do not include a fire or an evacuation (67% of ARs) are similar in duration to incidents without HAZMAT.
    - 1st stage: estimate the probability of a closure
    - 2nd stage: estimate the duration of that closure
    - Control facility location (mainline, siding, unknown) and occurrence of fire/evacuations

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Duration of Closure Results

- 1st stage: Probability of Closure by Incident Type (i) and Facility Type (f)

Facility Type (*f*)	No Evacuation or Fire (*i* =0)	Fire (*i* = 1)	Evacuation (*i* = 2)	Fire and Evacuation (*i* = 3)
Mainline	51%	51%	69%	90%
Siding/Yard	14%	14%	27%	56%
Unknown	28%	28%	46%	74%

- 2nd stage: Predicted Duration (Hours) Given a Closure by Incident Type and Facility Type

Facility Type (*f*)	No Evacuation or Fire (*i* = 0)	Fire (*i* = 1)	Evacuation (*i* = 2)	Fire and Evacuation (*i* = 3)
Mainline	18.5	68.3	18.5	41.1
Siding/Yard	6.0	22.2	6.0	13.4
Unknown	12.4	45.7	12.4	27.5

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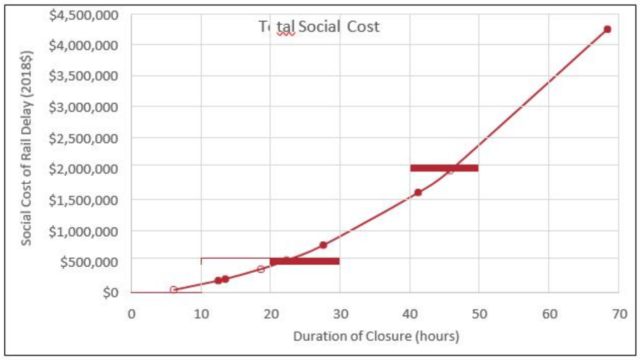
Duration of Closure Application



$$ExpectedSocialCost_{j=AR,l}$$

$$= 0.985 \times \sum_{f} p(f) \sum_{i} p(i|f) \times [q(i,f) \times SocialCost\,(l, d_{i,f}) - q(i=0,f) \times SocialCost\,(l, d_{i=0}\,)] + 0.015 \times \$0$$

Equation 1. Expected Social Cost of Delay due to HAZMAT in an AR

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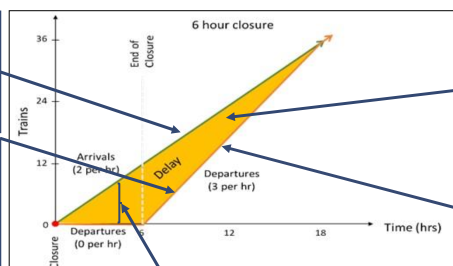
Cost of Waiting: Bottleneck Model

- The "bottleneck" model requires traffic level and the capacity of the track segment.

1. Green line represents the cumulative number of trains arriving at site for each hour. Arrival rate is 2 trains per hour.

2. The orange line represents cumulative departures. During hours 1 to 6, the track is closed so no departures. After hour 6, departures are 3 per hour – the capacity of the track segment.



5. The total delay is the entire orange area: the sum of the queue length over each hour

4. After the link is reopened, trains continue to arrive at the

same rate but the queue dissipates at the rate of the track capacity (3 trains per hour) until

3. The difference between the cumulative arrivals and departures is the queue length in any hour

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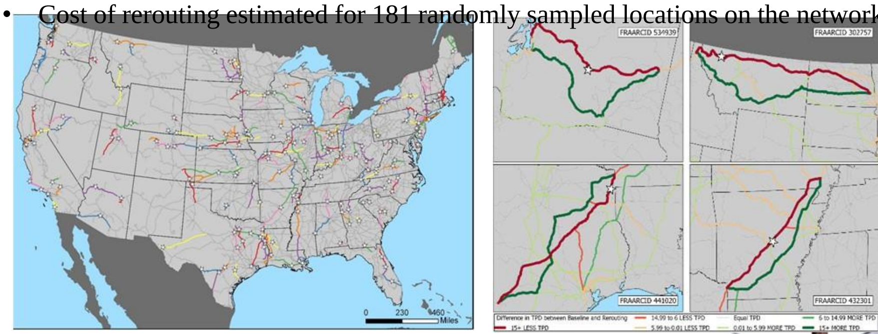
Cost of Rerouting

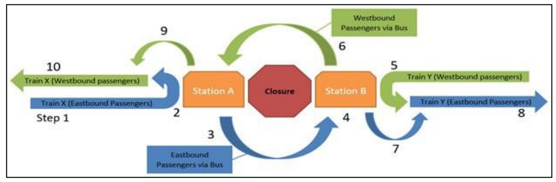
- To calculate the additional travel time involved in rerouting for a particular location, that network link was removed from the rail network and all waybill records were reflowed on modified network
- We estimate the increase in costs associated with the longer route
  - Currently performing additional analysis of cost of congestion on alternate route
- Cost of rerouting estimated for 181 randomly sampled locations on the network



Passenger and Road Cost of Delay

Other Costs

- Passenger Rail
  - Amtrak Intercity: “Bus Bridge”
  - Commuter: bus replacement



- Highway Cost of Delay taken from Hagemann et al (2013)

Incident Type or(*j*)	Percent with Road Closure Evacuation (m_j)
AR	71%
NAR	29%

Incident Type Rural(*j*)	Percent in Urban Area	Percent in Area
AR	65.2%	34.8%

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Initial Results (Currently Being Updated)

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Initial Results – Under Revision

- Non-Accident Releases (NARs)
  - 4-hour median Duration
  - RRs assumed to always wait
  - Average social cost of delay per NAR with closure: $28,000
  - 9.2 NARs with closures per year → $261,000 per year

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Initial Results – Under Revision

- Accident Releases
  - RRs decide to wait or reroute – chose option with lowest business costs
  - Those costs depends on location (see map)
  - Rerouting increases as duration increases
- Expected social cost of delay attributable to HAZMAT per AR: $85,860
  - 95 percent confidence interval of $39,241 to $132,479
  - 26.8 ARs per year → $2.3 million per year

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Next Steps

- Incorporate feedback from stakeholders and finalize results
  - Include estimates of congestion
  - Update unit values for social costs of emissions to include latest DOT guidance
  - Update model and data with new information from AAR and academic research
- Target for Final Report: Spring 2022

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Contact

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7.2.2 U.S. Census Bureau Commodity Flow Survey Presentation Slides

Commodity Flow Survey
Expanded Hazardous Materials Supplement

Trina Aime
U.S. Census Bureau

October 13, 2021
Pipeline and Hazardous Materials Safety Administration
Research, Development and Technology Forum

1

Commodity Flow Survey
Expanded Hazardous Materials Supplement

- Request from PHMSA to conduct an annual survey to provide estimates on the types of packaging used in shipping hazardous materials
- No survey currently collects detailed data on packaging of hazardous materials offered for transportation
- This level of data is critical to PHMSA and is needed to determine the impact of changes to hazmat shipping rules and regulatory requirements.

United States® Census Bureau

2

Commodity Flow Survey
Expanded Hazmat Data Collection

- Current plan integrates the PHMSA data collection request into the Commodity Flow Survey by expanding the hazardous materials data already collected
- Successful integration will result in a joint project between Census, BTS and PHMSA
  - Reduces funding needed from all three agencies as compared to separate, stand-alone surveys
  - Provides mandatory reporting authority for the PHMSA data collection
  - Utilizes shared resources currently working on the CFS
  - Reduces respondent burden

United States Department of Transportation Bureau of Transportation Statistics

United States™ Census Bureau

U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration

United States® Census Bureau

3

Commodity Flow Survey

- The Commodity Flow Survey (CFS) is a joint effort by the Bureau of Transportation Statistics (BTS) and the U.S. Census Bureau
- Conducted every 5 years as part of the Economic Census
  - Most recently in 2017 and next in 2022
- CFS collects data on the movement of goods within the United States
  - Captures the volume of hazmat transported
- Sample size of (approximately) 100,000 establishments (shippers)
- Sample establishments are requested to report four times during the year, once per quarter for a specific week in the quarter
  - Respondents report the total number of outbound shipments in the (specified) week
  - Then select a sample of those shipments and report information about the selected shipments.
- Estimates are produced on the: type, origin and destination, **value**, **weight**, modes of transportation, **distance shipped**, and **ton-miles** of commodities shipped

United States® Census Bureau

4

Commodity Flow Survey
Expanded Hazmat Data Collection Overview

- Additional questions on hazardous materials and packaging types collected as a CFS supplemental questionnaire
- Calendar Year 2021 PHMSA data collected with CFS Q1 (in March-April 2022)
- Calendar Year 2022 PHMSA data collected with CFS Q4 (in Dec-Jan2023)
- Increase hazmat shippers sampled – oversample NACIS with hazmat shippers and with as much variety of hazmat as possible.

United States® Census Bureau

5

Supplemental Survey Content Overview

- Exploratory Interviews and Cognitive Testing used to refine survey content.
- Begin with screener question in CFS main instrument. (Item C1)
- Create "roster" of hazardous materials shipped by an establishment (Item C2).
- Determine top 3 most frequently shipped hazardous materials (Item C3)
- Determine the type of packaging used creates 2 paths - Performance Oriented Packaging vs Specification Packaging (Item C5).
- Collect the packaging, quantity and mode for Top 3 hazardous materials on both paths (Item C6).

United States Census Bureau

6

Commodity Flow Survey
Expanded Hazmat Data Collection

Timeline

Activity	Timeframe
OMB Clearance	March 2022
Survey Instrument Completed	March 2022
2021 PHMSA Production Collection (2022 Q1 CFS Collection Cycle)	April – June 2022
Initial 2021 PHMSA Estimates Released	December 2022
2022 PHMSA Production Collection (2022 Q4 CFS Collection Cycle)	January – March 2023
Initial 2022 PHMSA Estimates Released	December 2023

United States Census Bureau

7

Next Steps

Review and analyze data

Tabulate estimates

Determine future of hazmat packaging data collection

8

For more information, please contact:

Trina Jenkins Aime, Program Manager
CFS Expanded Hazmat Data Collection
Economic Reimbursable Surveys
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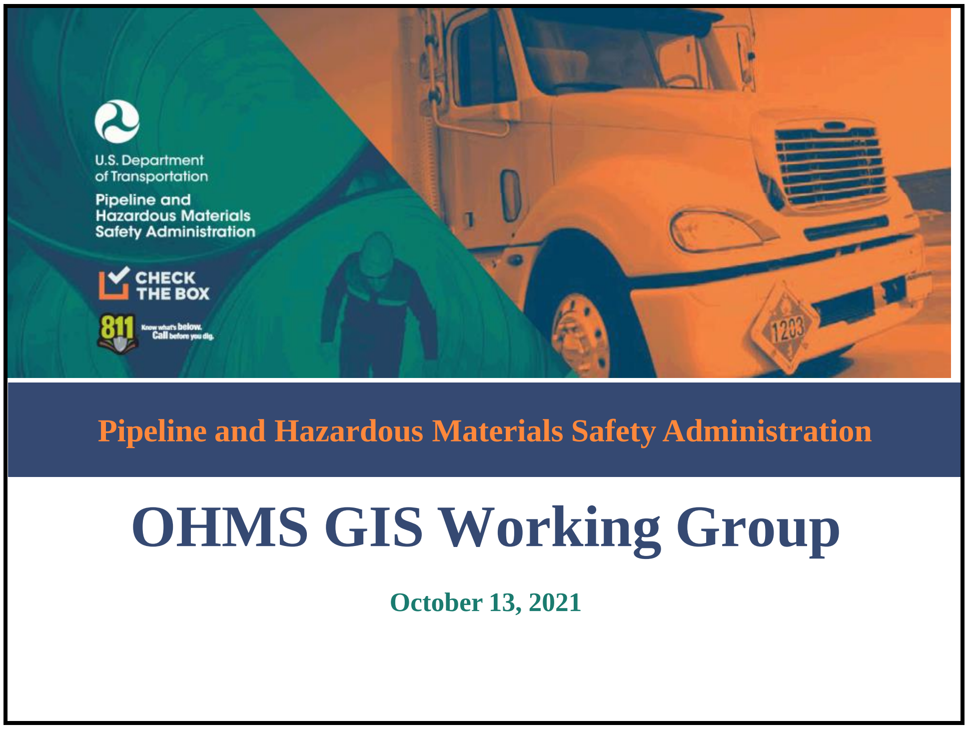
v

9

7.2.3 Geospatial Data and Hazardous Material Incidents Presentation Slides



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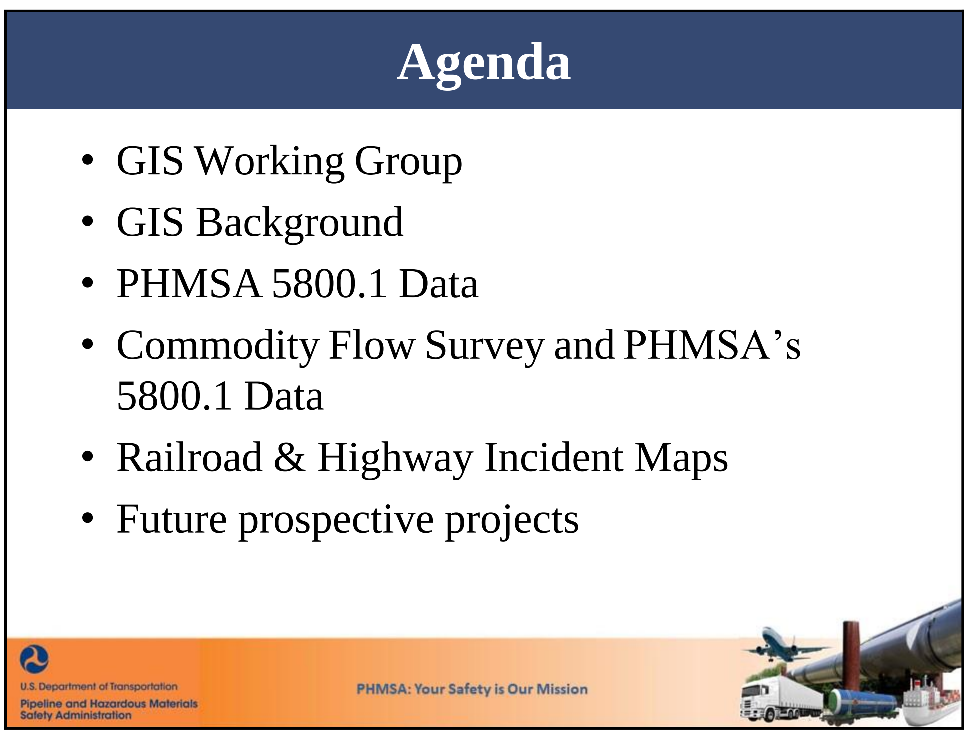


2

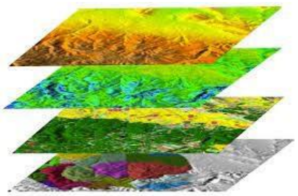
GIS Working Group

- How this group came about
- What does this group want to accomplish
- The goal of the working group
- Future plans for the working group

3

GIS Background

- What is a Geographic Information System (GIS)?



A spatial system that creates, manages, analyzes, and maps all types of data

4

PHMSA's Hazardous Material Incident Data (DOT 5800.1)

- Data Operations supports PHMSA's safety, environmental, and organizational excellence goals through collection and management of hazardous materials transportation incident information in the form of the DOT 5800.1 form.

- Incident data and summary statistics for previous years are provided to stakeholders.

- Users of PHMSA's Hazardous Materials Incident Statistic Reports now can view specific computer-generated incident reports representative of the DOT F5800.1 form.

Available Reports:

- **10 Year Incident Summary Reports**
- **Yearly Incident Summary Report**

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Potentially Reportable Incidents

- Objective: Identify and track potentially reportable HAZMAT incidents that may otherwise go unreported.
  - National Response Center (NRC)
  - Web-Sourced Incidents (WSI's)

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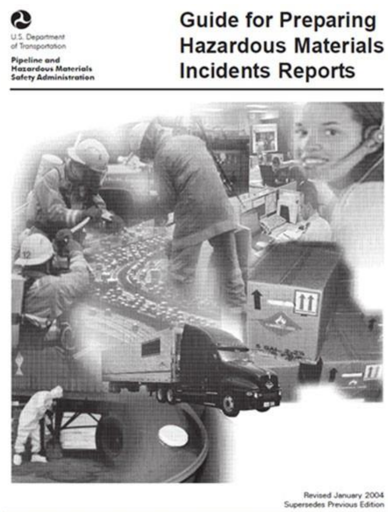
Incident Reporting



7

What is the purpose of the report?

The 5800.1 allows us to better understand the causes and consequences of hazardous material transportation incidents.

The data is used to identify trends and provide basic program performance measures.

It helps to demonstrate the effectiveness of existing regulations and to identify areas where changes should be considered.

It also assists all parties, including industry segments and individual companies, to understand the types and frequencies of incidents, what can go wrong, and possible measures that would prevent their recurrence.

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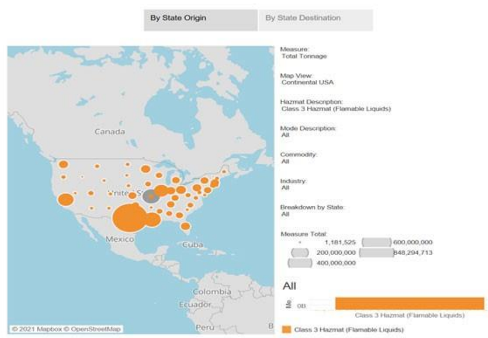
Using Commodity Flow Data in GIS

- What is Commodity Flow Survey
- What data are we using from the survey
- Why use CFS data?



Meaning of Mode category ...	Year	Value ($ million)	Value (percent change)	Tons (thousands)	Tons (percent change)
All modes	2012	2,334,425	61.2	2,580,153	15.6
All modes	2017	1,680,231	-28.0	2,967,965	15.0
Single modes	2012	2,304,743	68.2	2,552,868	20.9

Source: Bureau of Transportation Statistics & US Census Bureau

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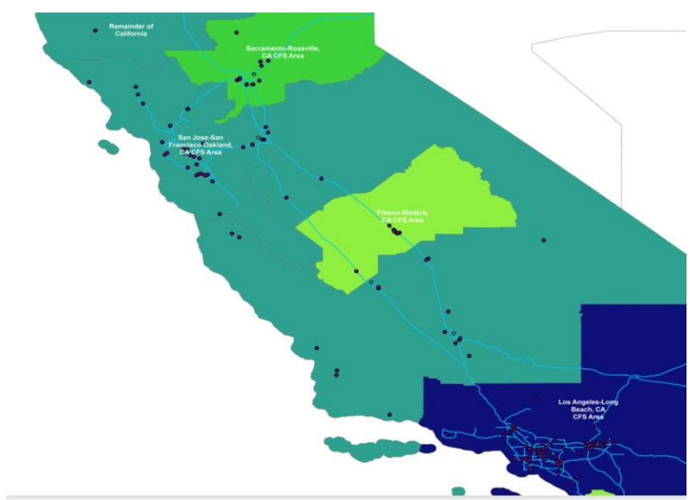
CFS and PHMSA’s 5800.1 Data



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Railroad GIS Map

Class 3 Railroad Incidents 2015 – 2020 (448 records)

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Highway GIS Map

Class 3 Highway Incidents 2015 – 2020 (1854 records)

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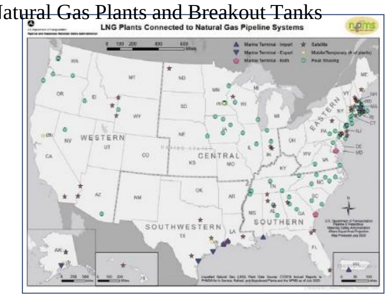
OPS - NPMS

US DOT npms national pipeline mapping system

- More than a pipeline map…
  - Spatial and attribute history on each pipeline segment
  - Accident and incidents associated to pipe segments to track asset history
  - Underground Natural Gas Storage, Liquefied Natural Gas Plants and Breakout Tanks
  - PHMSA inspection boundaries
  - High Consequence Area GIS data
  - 7 Web Mapping Applications and many tools
  - Monthly support to over 40,000 stakeholders
- More than a collection of data…
  - Inspection planning and analysis
  - Accident and incident investigations
  - Emergency response
  - Risk analysis and resource allocation
  - Policy analysis and engineering research
  - Public Awareness, outreach and support for emergency responders and pipeline safety initiatives at all levels of government



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Future Prospective Projects

Down the road...

- Vulnerability index (CDC) – environmental justice and equity
- Census keeps track of fire/police - route analysis
- Route quality (highways) - analyzing current hazmat highway routes
- Trending of incident occurrences by year and spill releases
- Rulemaking/rule changes – effects on incidents
- Database of major carriers/receivers of hazmat and their routes
- Live mapping of incidents

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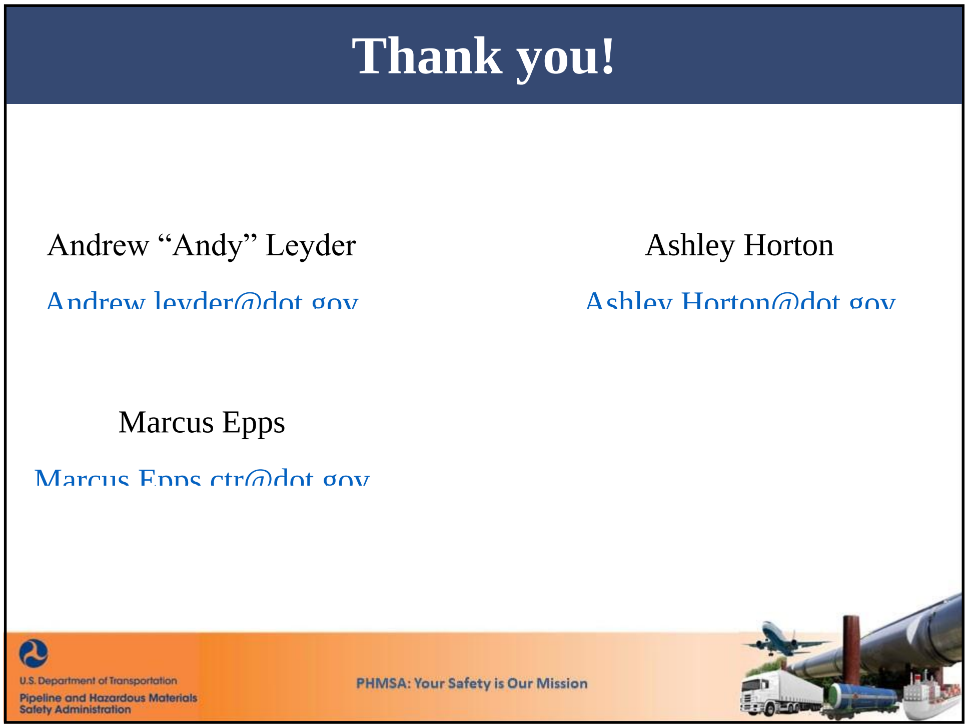

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7.3 Day 3 Presentation Material

7.3.1 Default of Classification of Explosives (Thermite) Presentation Slides

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Safety Management Services, Inc. (SMS®)

- The mission of SMS is to safeguard people, processes, and the environment.
  - Systematic identification of safety-related deficiencies
  - Development and implementation of solutions based on sound principles.
- Expertise in the safe processing and handling of energetic materials and hazardous chemicals
  - Manufacturing
  - Transportation
  - Storage
  - Handling

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Safety Management Services, Inc. (SMS)

- One of the U.S. DOT PHMSA Explosive Labs since 1998
  - Five approved examiners
- Comprised of around twenty-five explosives safety professionals from various disciplines
  - Chemical engineering (PhD, PE, CSP)
  - Mechanical engineering (PE)
  - Physics (PhD)
- Public-Private-Partnership (P3) with the Tooele Army Depot in Tooele, Utah

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SMS-TEAD Partnership

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SMS Affiliations

- Explosives Testing Users Group (etusersgroup.org)
  - US national laboratories (DoD, DOE, FBI, ATF, DHS…)
  - International laboratories (CERL, TNO, BAM, HSL, …)
- SAAMI Delegation to the United Nations (UN)
  - UN Explosives Working Group (EWG)
  - Transport of Dangerous Goods Subcommittee
  - Global Harmonization Subcommittee
- Training and Consulting, LLC (TCI)
  - Classification of Explosives for Transport
  - Advanced Facility Siting & In-Process Classification
  - Process Safety Management (PSM) & Hazards Analysis

ET Users Group

SAAMI
SPORTING ARMS AND AMMUNITION MANUFACTURERS' INSTITUTE, INC.
SINCE 1926

tci Training and Consulting, LLC

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Overview

- Research study to understand thermite families
- Eight (8) Large-scale test samples
  - UN Tests N.1, N.4 and N.5 for flammable solids
  - UN Test Series 2, 3 and 6 for potential explosives
- Twenty-three (23) Small-scale test samples
  - Auto-ignition temperature
  - Hot-wire sensitivity

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Introduction to Thermites

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Introduction to Thermites

- Thermites are traditionally a mixture of metal powder and metal oxide powder that release large amounts of heat upon ignition:

$$metal_1 + metal\ oxide_2 \xrightarrow{\text{ignition}} metal\ oxide_1 + metal_2 + heat$$

- Metal powders include aluminum, magnesium, titanium, etc.
- Metal oxides include iron oxide, copper oxide, chromium oxide, manganese oxide, etc.

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Introduction to Thermites

- Large-scale thermite mixes (eight total)
  - Three thermites were commercially available
  - Five were mixed by SMS from very fine powders (1 - 5 micron)

- Small-scale thermite mixes (twenty-three total)
  - Mixed by SMS from very fine powders

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Introduction to Thermites

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Characterization of Thermites

UN Test N.1

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Characterization of Thermites

- UN Test N.1
  - Ignition of sample
    - Gas torch
    - Hot wire

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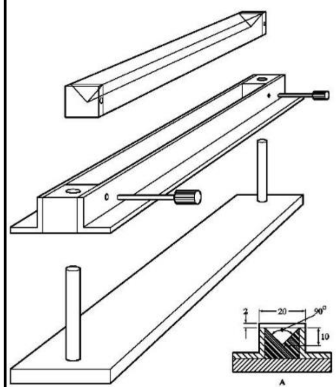
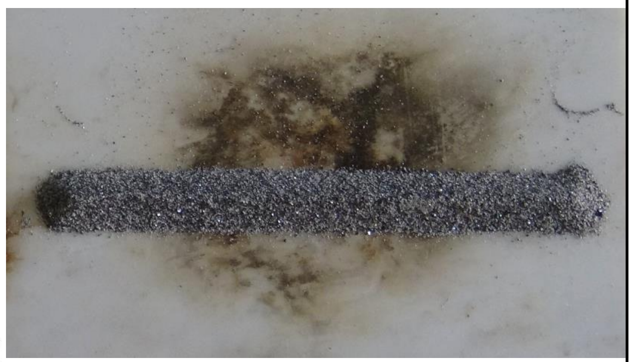
Characterization of Thermites





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Test N.1: Large-scale Mix ID #1 (ignition with transition to low-order explosion)

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Test N.1: Large-scale Mix ID #2 with torch (no reaction)

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Test N.1: Large-scale Mix ID #2 with Mg strip (no reaction)

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Test N.1: Large-scale Mix ID #4 using Torch (ignition without sustained burning)

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Test N.1: Large-scale Mix ID #4 using Hot Wire (ignition without sustained burning)

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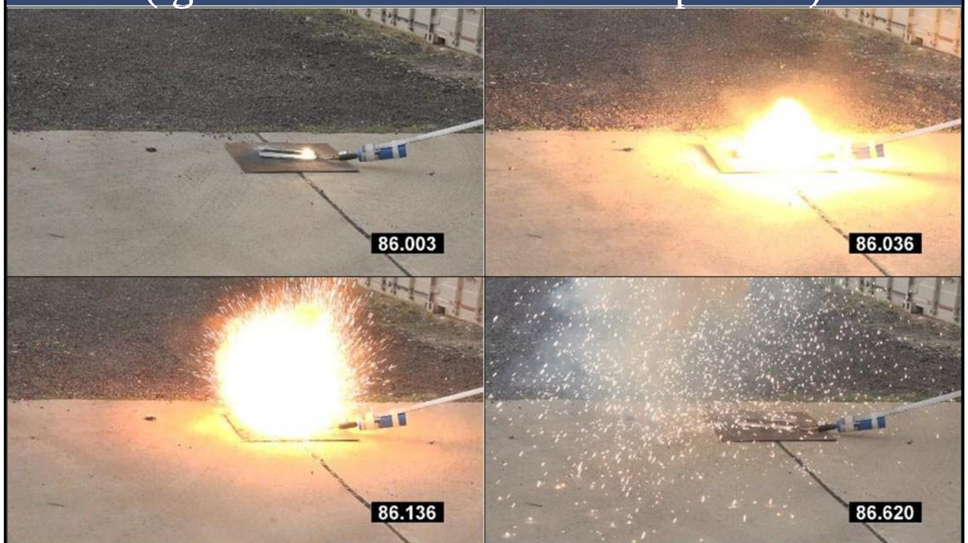
Test N.1: Large-scale Mix ID #7 (ignition with transition to explosion)



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Test N.1: Large-scale Mix ID #8 (ignition with transition to explosion)

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Characterization of Thermites

- Sample width results in reaction dying out
  - ISSUE: Thermites often pass this test, appearing to not be flammable solids with elevated burning rates
    - Offered for shipment as non-regulated if based on this test alone but with the potential to burn vigorously

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Characterization of Thermites

- Large-scale UN Test N.1
  - Wider sample width results in full propagation
  - Crucible style test (optional)
    - Cannot use hot wire ignition
  - Ignition of sample
    - When insufficient for ignition: alternate ignition sources?
    - Desire to use ignition method from field usage

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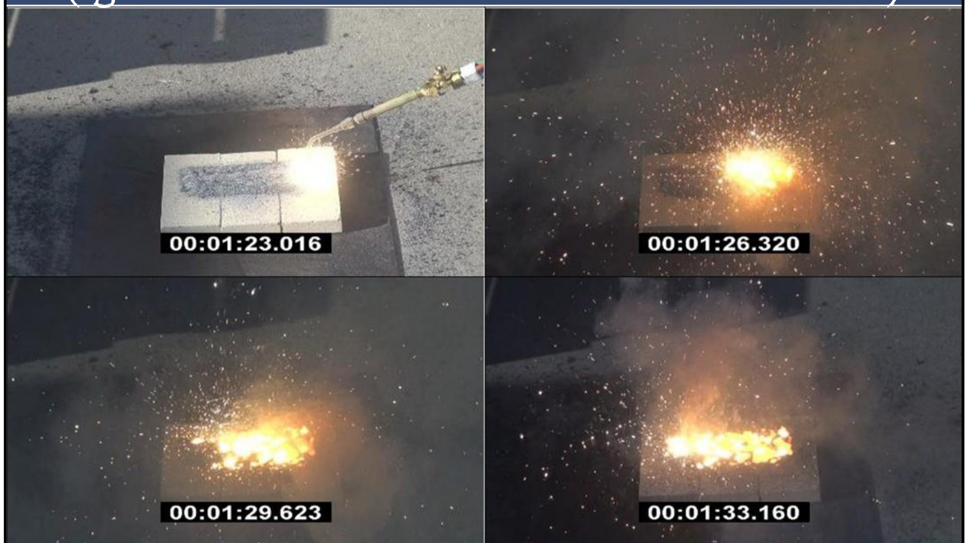
LS Test N.1: Large-scale Mix ID #2 (ignition with sustained reaction over 10 secs)



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LS Test N.1: Large-scale Mix ID #2 (ignition with sustained reaction over 2.7 secs)

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LS Test N.1: Large-scale Mix ID #4 (ignition with sustained burning)

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LS Test N.1: Large-scale Mix ID #4 (ignition with sustained burning)

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LS Test N.1: Large-scale Mix ID #7 (ignition with transition to explosion)

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Characterization of Thermites

- In a large-scale N.1 test, thermite mixtures may exhibit burning rates in excess of 2.2 mm/sec (see 49 CFR 173.124(a)(3)(ii))
  - NOTE: The current UN Test N.1 test methodology could potentially permit these powders to be offered for transport as non-regulated goods
    - Powder train pile is too narrow to sustain propagation
    - Ignition source utilized around 1000 °C (below auto-ignition temperature)

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Characterization of Thermites

UN Test Series 2 & 3

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UN Series 3

- Small-scale tests to determine safe handling parameters and whether the substance is forbidden from transport
  – Impact sensitivity
  – Friction sensitivity
  – Thermal stability at 75 °C for 48 hours
  – Small-scale burning for 100 grams

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3 (d) Small-scale Burning

- Four thermites did not ignite
- Two thermites ignited and burned
- Two thermites transitioned to explosion

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Test 3 (d): Large-scale Mix ID #1 (ignition with sustained burning)

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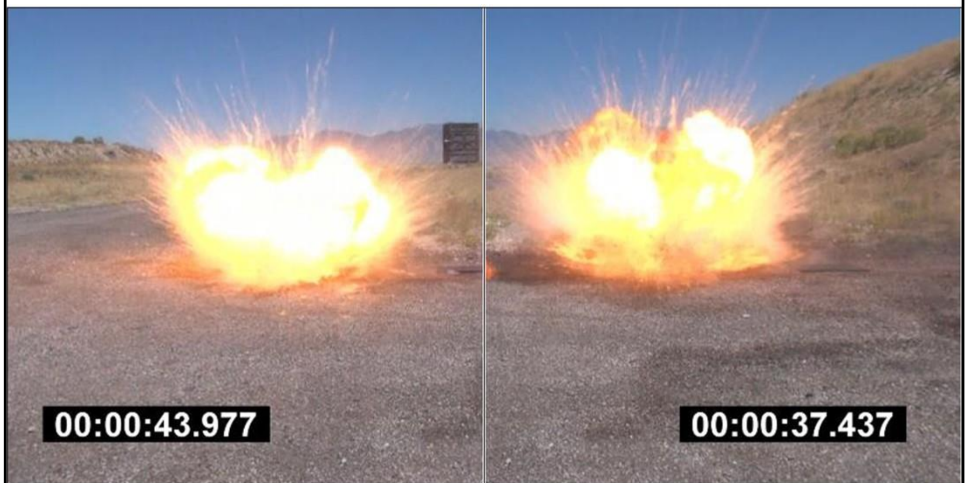
Test 3 (d): Large-scale Mix ID #8 (ignition with transition to explosion)



33

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UN Series 2

- Presence of explosive properties
  - UN Gap
    - Shock under confinement
  - Koenen
    - Heating under confinement
  - Internal Ignition
    - Ignition under confinement

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Characterization of Thermites

- UN Series 3
  - Mix ID's 7 & 8 exploded in small-scale burning test
  - Otherwise, all passed the test criteria
- UN Series 2
  - All thermites passed UN 2-in gap and Internal Ignition
    - Even those that explode when ignited by flame
    - Needed to use an alternate ignition source
      - Pyrogen igniter
      - Pyrogen igniter with 10-grams of fine, long-burning thermite
  - Mix ID's 7 and 8 failed the Koenen test

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Characterization of Thermites

- UN Series 6 Package and Fire tests
  - Mix ID 7 & 8 readily transitioned to explosion when unconfined
  - Nearly all damaged 2-mm thick aluminum
  - Some damaged 3-mm thick mild steel
- UN Series 7 (e) EIS External fire test
  - Mix ID's 1, 7, and 8 showed an elevated reaction hazard when heated under confinement
  - Mix ID's 2 and 3 did not react in liquid fuel fire

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Characterization of Thermites

- UN Test N.4 (self-heating)
  - All passed the test criteria
- UN Test N.5 (dangerous when wet)
  - Many of the fine SMS-mixed thermites failed the test criteria
  - All commercially available thermites passed the test criteria

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Proposed Classifications for Large-Scale Thermite Test Samples

Mix ID	Most Critical Tests	Proposed Classification
1 (Fine)	UN Series 3 (d), Unconfined 6 (a), Sub-scale 6 (c), Sub-scale 7 (e); also UN Test N.1, Large-scale UN Test N.1, and UN Test N.5. Could pose a potential threat to the structural integrity of an aircraft.	**Division 1.3 or 1.4 with subsidiary Division 4.3 hazard - FORBIDDEN FROM AIRCRAFT**
2 (Coarse)	Large-scale UN Test N.1 test results using an alternative ignition method. Could pose a potential threat to the structural integrity of an aircraft.	**UN3178, Flammable solid, inorganic, n.o.s., 4.1, PG II - FORBIDDEN FROM AIRCRAFT**
3 (Coarse)	Large-scale UN Test N.1 test results using an alternative ignition method. Could pose a potential threat to the structural integrity of an aircraft.	**UN3178, Flammable solid, inorganic, n.o.s., 4.1, PG II - FORBIDDEN FROM AIRCRAFT**
4 (Fine)	UN Series 3 (d), Unconfined 6 (a), Sub-scale 6 (c) External fire (bonfire); also the Large-scale UN Test N.1. Could pose a potential threat to the structural integrity of an aircraft.	**Division 1.3 or 1.4 with subsidiary Division 4.3 hazard - FORBIDDEN FROM AIRCRAFT**

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Proposed Classifications for Large-Scale Thermite Test Samples

Mix ID	Most Critical Tests	Proposed Classification
5 (Med)	Unconfined UN Series 6 (a) Single package, UN Test N.1 and the Large-scale UN Test N.1. Could pose a potential threat to the structural integrity of an aircraft.	**Division 1.3 or 1.4 with subsidiary Division 4.3 hazard - FORBIDDEN FROM AIRCRAFT**
6 (Fine)	UN Series 2 (b) Koenen; also UN Test N.1 and the Large-scale UN Test N.1 subsidiary hazard as Division 4.3 PG III based on UN Test N.5 test results. Could pose a potential threat to the structural integrity of an aircraft.	**Division 1.3 or 1.4 with subsidiary Division 4.3 hazard OR UN3178, Flammable solid, inorganic, n.o.s., 4.1, (4.3), PG II - FORBIDDEN FROM AIRCRAFT**
7 (Fine)	UN Series 3 (d), Unconfined 6 (a) Single package, Sub-scale 6 (c), Sub-scale 7 (e); also UN Test N.1, Large-scale UN Test N.1, and UN Test N.5. Could pose a potential threat to the structural integrity of an aircraft.	**UN0476, Substances, explosive, n.o.s., 1.1G, (4.3), PG II**

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Proposed Classifications for Large-Scale Thermite Test Samples

Mix ID	Most Critical Tests	Proposed Classification
8 (Fine)	UN Series 3 (d), Unconfined 6 (a) Single package, Sub-scale 6 (c), Sub-scale 7 (e); also UN Test N.1, Large-scale UN Test N.1, and UN Test N.5. Could pose a potential threat to the structural integrity of an aircraft.	**UN0476, Substances, explosive, n.o.s., 1.1G, (4.3), PG II**

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Characterization of Thermites

- Seven fine thermites transitioned from burning to explosion when unconfined
- Two fine thermites produced low-order explosions

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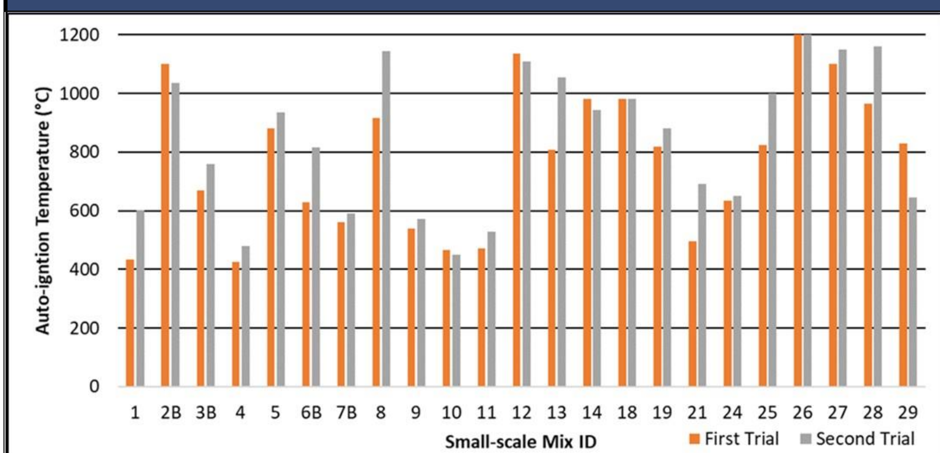
Auto-ignition Temperature of Thermites



The average auto-ignition temperature of the twenty-three small-scale thermite test samples was 809 °C with a standard deviation of 240 °C.

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Conclusions

Traditional UN tests for flammable solids and explosives may not accurately communicate the hazard presented by thermites

- High temperatures needed to initialize reaction
- Critical mass / width may be needed to sustain combustion
- Confinement elevates an explosive's reaction hazard
  - Confinement of thermites appears to lessen the reaction hazard
- Further research needed to understand the hazard presented by thermites in transport

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7.3.2 Lithium Battery Air Safety Advisory Committee Presentation Slides

Lithium Battery Air Safety Advisory Committee

Steve Webb

Pipeline and Hazardous Materials Safety Administration
Office of Hazardous Materials Safety

International Program
Transportation Specialist

October 2021

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Outline

Purpose: To provide an update to the Research, Development, and Technology Research Forum

- International Program Overview
- Lithium Battery Air Safety Advisory Committee
- Report to Congress and the Secretary

2

International Program Overview

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UN Global Safety Framework

United Nations Economic and Social Council (ECOSOC)

- United Nations Sub-Committee of Experts on the Transport of Dangerous Goods (UN TDG)
  - Multi-Modal transport standards
  - Established in 1954
  - UN Recommendations published in 1956
  - US Hazardous Materials Regulations adopted in 1991 (HM-181)
  - Reformatted as UN Model Regulations in 1996
  - PHMSA Head of Delegation and TDG Chair
- United Nations Sub-Committee of Experts on the Globally Harmonized System of Classification and Labelling of Chemicals (UN GHS)
  - Established in 1992 – UN Conference on Environment and Development
  - Extended mandate as a Sub-Committee with TDG in 1996
  - TDG designated as physical hazard focal point
    - UN Manual of Tests and Criteria
  - OSHA adopted in 2012 (HAZCOM 2012)
  - OSHA is Head of Delegation, PHMSA jointly participates

International Regulatory System

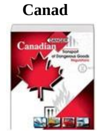
The UN Model Regulations serve as the basis

Ai | **Maritim** | **U.S.** | **Canad** | **Europ**

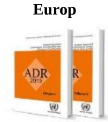
ICAO Technical

IMDG

U.S. Hazardous Materials



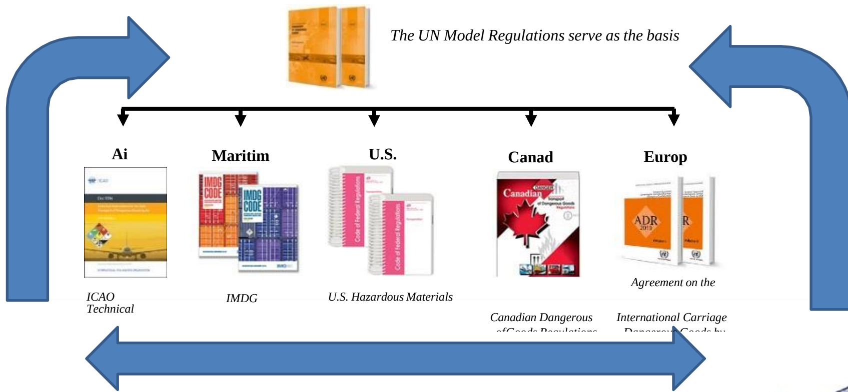
Canadian Dangerous Goods Regulations



European Agreement on the International Carriage of Dangerous

5

International Regulatory System



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Lithium Battery Air Safety Advisory Committee (LBC)

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LBC

- Lithium Battery Air Safety Advisory Committee
  - Federal Advisory Committee to facilitate communication between lithium battery and cell manufacturers, shippers, users, transporters, and the Federal government to seek stakeholder input relating to lithium battery transportation safety
  - Met in Sept of 2021 & next meeting in March of 2022

2

8

LBC

- Committee focus areas include four Sub-Committees
  - Data Collection & Analysis
  - Regulations & Gap Analysis
  - Supply Chain Safety & Integrity
  - Hazard Review
- ICAO related inputs
  - G27
  - Section II
  - Batteries in & with Equipment
  - Simplifying Regulations
  - UN Classification

PIPELINE AND HAZARDOUS MATERIALS SAFETY ADMINISTRATION (PHMSA)
LITHIUM BATTERY AIR SAFETY
ADVISORY COMMITTEE

2

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LBC Report

Submitted a report to Congress and the Secretary with recommendations to advance lithium battery air transport safety

Recommendations Include:

- Establish an enhanced lithium battery and equipment incident reporting system/database to capture information beyond what is required by regulation or provided through existing reporting mechanisms. Provide appropriate stakeholders with data and analysis from reporting mechanism

2

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LBC Report

Recommendations (cont):

- Create a process for forensic evaluation and root cause analysis of lithium batteries and equipment involved in an aviation related incident.

- Define all necessary supply chain data and information relevant to aviation to ensure or improve transportation safety, including the optimal means to store, access, and deliver this accurate and verifiable information.

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LITHIUM BATTERY AIR SAFETY
ADVISORY COMMITTEE

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LBC Report

Recommendations (cont):

- Engage with battery manufacturers and the aviation sector to better define the risk profile of batteries shipped in cargo compartments, and effectively implement adequate SMS principles.

2

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Thank You!

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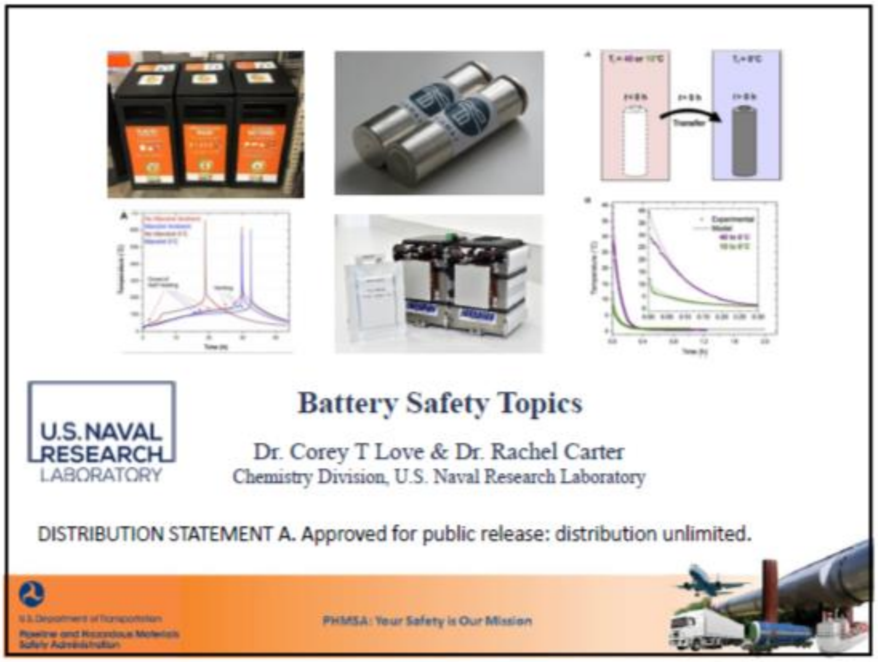
7.3.3 U.S. Naval Research Laboratory Lithium-Ion Battery Research Presentation Slides



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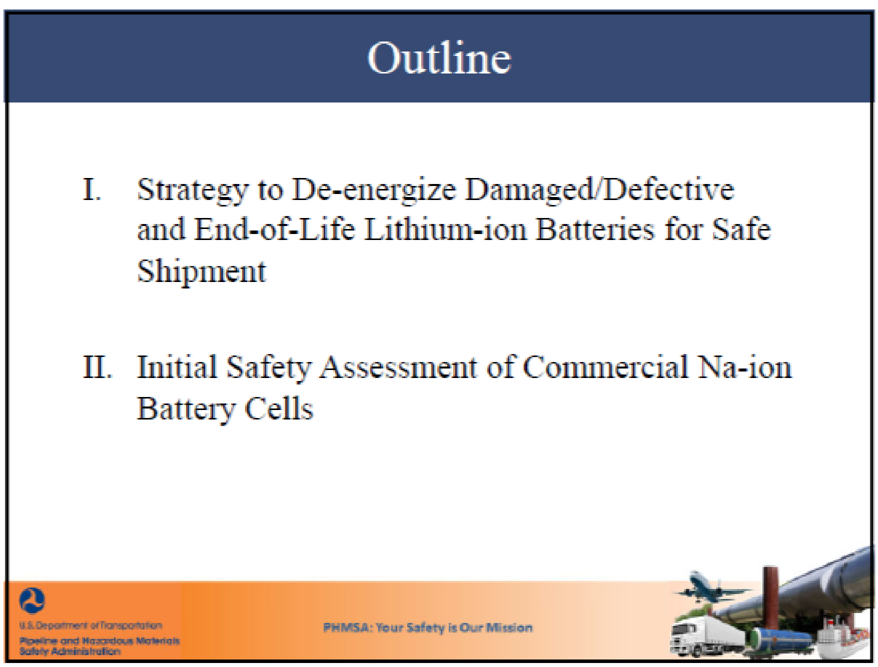

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Motivation

Increased government investment and interest in lithium-ion battery recycling equates to more damaged/defective/end-of-*life* batteries in transport.

"Train car carrying Lithium batteries explodes near downtown Houston" -KHUA11 April 23, 2017

There is a need to ensure safe transportation of these batteries from collection centers to recycling and waste facilities.

Spent battery collection point at major retailer

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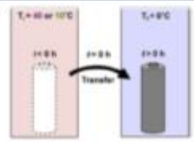
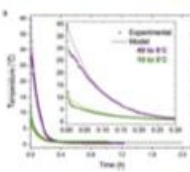
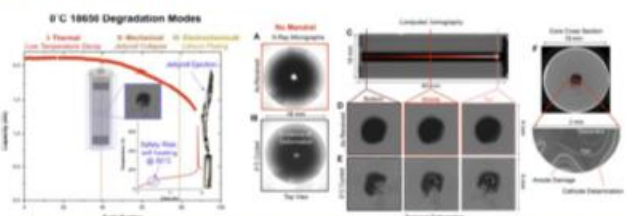
Objective

No inexpensive, efficient processes exist to de-energize cells at the point of collection prior to transport.

Our goal is to develop a simple, coupled, electrical and thermal method to de-energize lithium-ion cells.







Carter, R.E.; et al. Detection of Lithium Plating During Thermally Transient Charging of Li-ion Batteries. *Frontiers in Energy Research* **2019** (7).

Carter, R.E.; et al. Mechanical collapse as primary degradation mode in mandrel-free 18650 Li-ion cells operated at 0°C. *J Power Sources* **2019** (437) 226820.

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Approach

Demonstrate a simple technique to achieve electrical + thermal deactivation of lithium-ion cells.

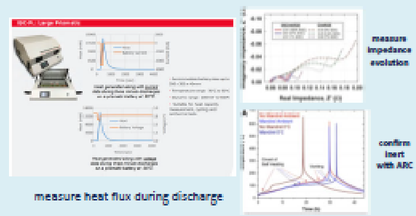
Must be easy to implement, require minimal infrastructure and produce modest waste stream.

Application is targeted for utility at collection facilities and recycling depots.

Heat Generation during Rapid Discharge:

i = max current draw; R will increase with aging

Measurements of Resistance & Heat Flux:



measure heat flux during discharge

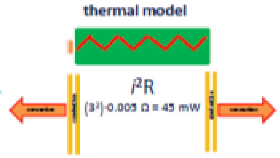
5

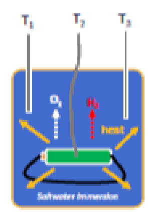
Experimental Variables

What are the critical parameters for immersion solution?
Salt: selection, concentration.
Temperature: below 0°C, isothermal, thermal transient (low T to high T).
Volume: liters of bath needed to dissipate heat

Properties to measure:
Heat flux from discharging cell.
Immersion bath temperature increase.
Ionic/thermal conductivity of immersion bath.
Reactivity of cell after immersion treatment.

Combined electrical & thermal model





Example guidance:

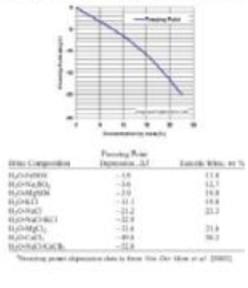
50 Ah
(10 lbs. of batteries)
3M Na_2SO_4
1 L Volume

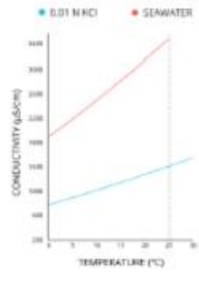
Deliverables: Prescribe an optimal immersion bath (salt, salt concentration, temperature) and throughput (Ah per volume of immersion bath)

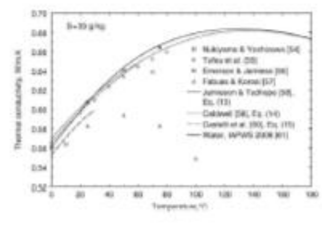
6

Physical Property Relationships

Temperature ↓ Battery Reactivity ↓
Salt Conc. ↑ Freezing Point ↓
Salt Conc. ↑ Electrical Conductivity ↑ Discharge current ↑ De-energize Time ↓
Temperature ↓ Electrical Conductivity ↓ Thermal Conductivity ↓







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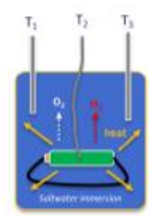
Research Plan

1. Market survey
2. Develop methodology
3. Optimize immersion bath parameters
4. Applicability for larger systems

SCALE	CAPACITY	VOLTAGE	ENERGY	EXAMPLES
Individual Cell	≤ 3 Ah	≤ 5 V	15 Wh	coin cells, 18650, pouch cells 
Small Battery	10 Ah	5 - 11 V	50 Wh	e-scooter, laptop batteries, 6 x 18650 
Large Battery	100 Ah	11 - 25 V	2.5 kWh	Li-ion automotive drop-in replacement battery 



50 Ah
(10 lbs. of batteries)
3M Na_2SO_4
1 L Volume

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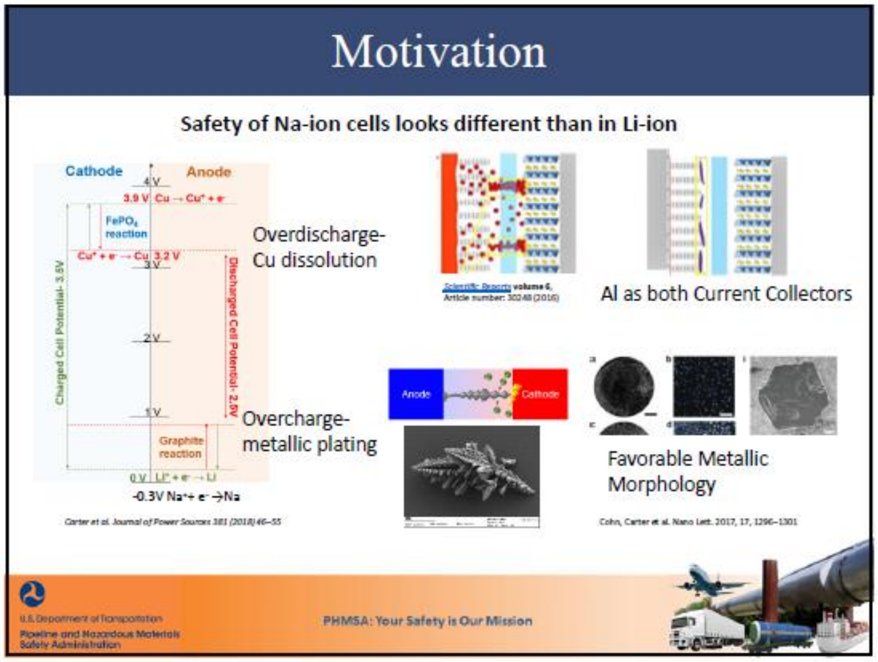
Motivation
Safety of Na-ion cells looks different than in Li-ion
Cathode
Anode
4 V
3.9 V Cu → Cu⁺ + e⁻
FePO₄ reaction
Cu⁺ + e⁻ → Cu 3.2 V
3 V
2 V
1 V
Charged Cell Potential- 3.5V
Discharged Cell Potential- 2.9V
Graphite reaction
0 V Li⁺ + e⁻ → Li
-0.3V Na⁺+ e⁻ →Na
Carter et al. Journal of Power Sources 381 (2018) 46–55
Overdischarge-
Cu dissolution
Scientific Reports volume 6, Article number: 30248 (2016)
Al as both Current Collectors
Anode
Cathode
Overcharge-
metallic plating
Favorable Metallic
Morphology
Cohn, Carter et al. Nano Lett. 2017, 17, 1296–1301
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Motivation
Materials and Components vary under the Na-ion Category
Cathode
Na-ion Battery
Anode
Electrolyte & Binder
Chem. Soc. Rev., 2017, 46, 3529-3614
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10

Research Approach

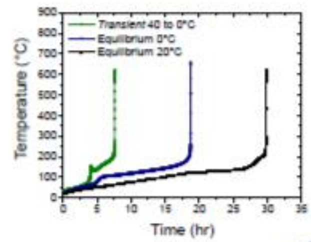
Characterize failure modes
- Different SOCs
- Nail Penetration
- External Heating

Fig.1.
NPCD hardware

NRL Code 6173 Safety Facility

Fig.2.
Nail penetration unit in-situ with an 18650.

Accelerated Rate Calorimetry to Assess Thermal Runaway Behaviors



11

Market Research

Boasting: High current, long life, safety

Company (Origin)	Nominal Voltage (V)	Nominal Energy Density (Wh/kg)	Cathode Material	Unit Cell Size (g); type	Other Notes
Samsung Li-ion (Korea)	3.7	263	NMC NiMnCoO	48 18650	High energy
A123 Li-ion (MA, USA)	3.2	110	LFP $FePO_4$	39 18650	High safety; high power
Natron (CA, USA)	1.8	22	Prussian Blue Na2Fe[Fe(CN)6]	305 Pouch	High safety/low energy; aqueous; *20 cells acquired*
Tiamat (France)	3.6	130	NVP Phosphate $Na_3VO_x(PO_4)_2F_y$	33 18650	*30 cells purchased*
Faradion (UK)	3.1	150	Layered metal oxide $NaNi_{1-x-y-z}M^1_xM^2_yM^3_zO_2$	600 Pouch	Shipped shorted; competitive with LFP; 18650 available; *300 cell procurement including 12 V pack with BMS*
Altris (Sweden)	3.2	~100	Prussian White (R-Na1.92Fe[Fe(CN)6])	cylindrical	No product yet; competing with CATL
LiNa (UK)	2.6	~100	High temperature chemistry (SS) $NiCl_2$	Pouch	No product yet; Solid state

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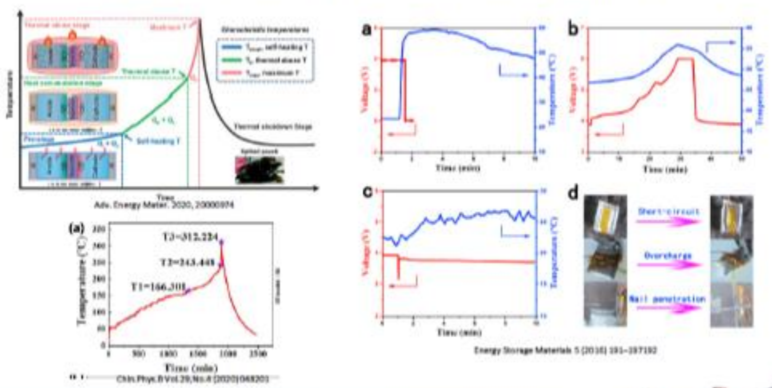
Anticipated Results

Evidence from literature shows reduced thermal and physical risk



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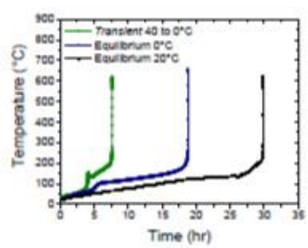
Research Plan

1. Market Research
2. Cell Procurement
3. Destructive Thermal Analysis
4. Nail Penetration/Crush Testing



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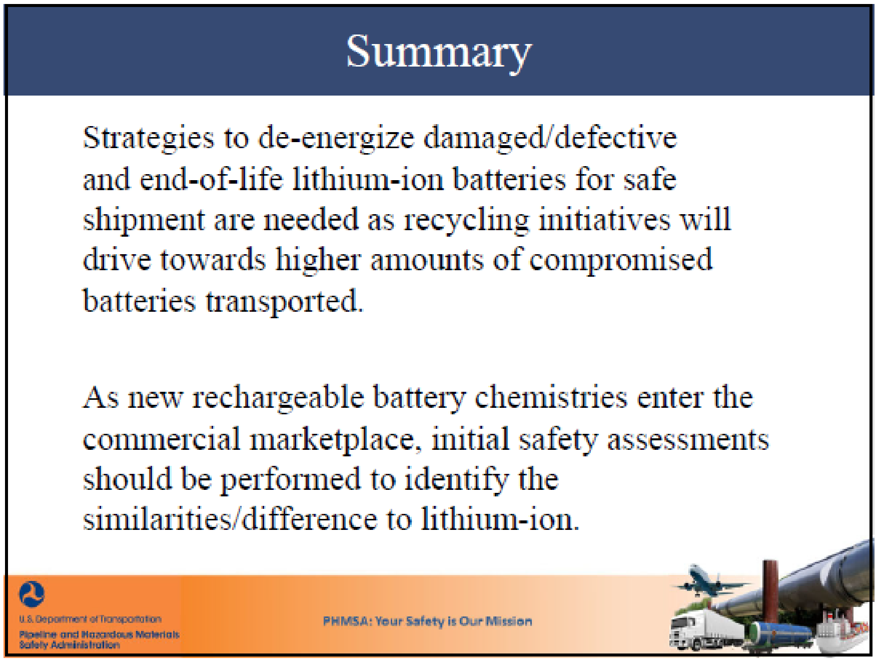

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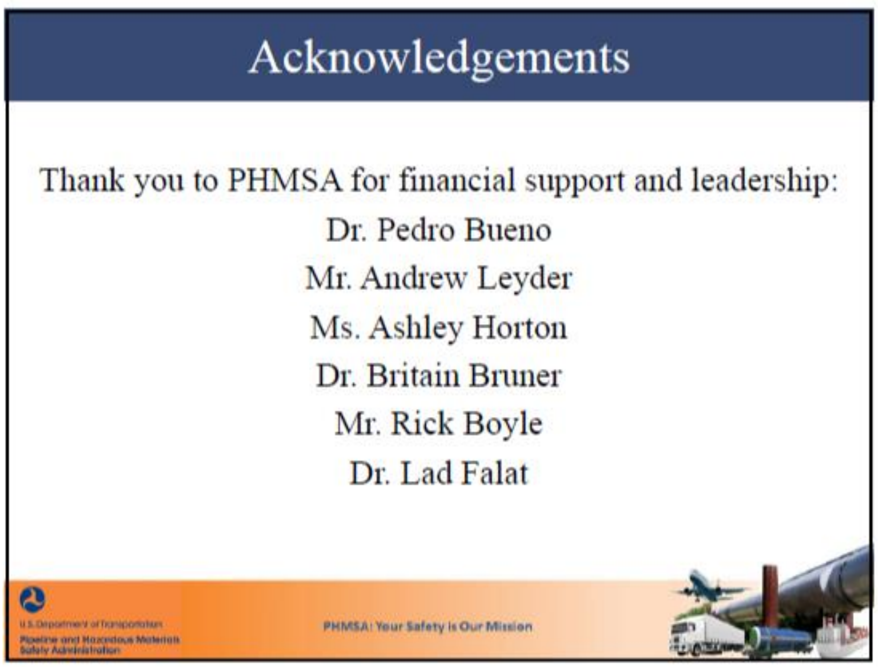

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7.4 Day 4 Presentation Material

7.4.1 Composite Metal Foams for Impact Protection of HM Transportation Presentation Slides

Composite Metal Foams for Impact Protection of Hazardous Material Transportation

Project Contract Number: 693JK320C000009

Afsaneh Rabiei

Professor, Mechanical and Aerospace Engineering, NCSU (arabiei@ncsu.edu)

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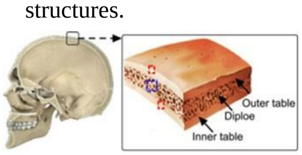
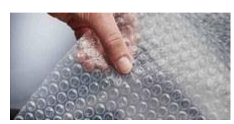
The Art of Engineering: Learn from Nature

- The human skull is made from porous bone to **protect** the brain from impact while it is **light weight** allowing for **maneuverability**.
- **Bird bones** are lightweight yet strong to support flight. **Bird beaks** have cellular structures to protect against repeated impact & vibration with low weight providing **maneuverability**.
- Grass and plants structure are made porous and as such they are light weight and resist stepping on them repeatedly
- **Still air** prevents **thermal transmission** while the act of compressing **air absorbs energy.**
- **How do we learn from nature**? By introducing *air trapped inside porosities of metals*, we can create lightweight products that protect against impact, absorb vibrations and sounds, stop blasts, ballistics, and frags, shield from radiation, EM, and RF, and protect against fire and extreme heat, allowing for the manufacturing of advanced and more efficient protective structures.





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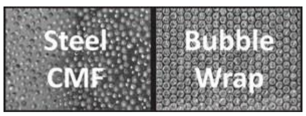
Composite Metal Foam (CMF)

- Composite Metal Foam is a novel class of porous material with 30-35% metal and 65-70% airtrapped within hollow metal spheres.
- CMF works like a heavy-duty bubble wrap that can be created out of nearly any metal, alloy,or combination and can be fine-tuned per application.

– Via civilian, academic, and military testing, CMF has proven to absorb energy at a rate 2 orders of magnitude higher than its bulk, solid parent material.

– CMF protects against high-speed impact, ballistics, blast and frags, nuclear radiation, heat, sound and vibration, and more and a third of the weight.
of aluminum.



CMF looks and acts like bubble wrap, absorbing energy via the compression of air trapped inside.

Solid Steel   Steel-Steel CMF

A solid steel block weighs 3 times more than a steel CMF block of equal size.

CMF absorbs energy via compression and collapsing of the hollow metal spheres

Composite Metal Foam has been developed with help from the following below.

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Composite Metal Foam (CMF)

- 4 US Utility Patents are issued on the processing of Composite Metal Foam via 2 techniques (casting and power metallurgy pressing and sintering). All patents have beenreleased to Advanced Materials Manufacturing, LLC (AMM) for commercialization of the material for global markets.
- Advanced Materials Manufacturing, LLC is a spin off from NC State University that isnow operating independently from the university, striving for the commercialization ofCMF.
- CMF is currently at a TRL of around 6 in certain applications such as vehicle armors andthe transportation of HAZMAT and explosives.

Patent #	Date Issued	Type	Inventor
7641984	January 5, 2010	US Utility Patent	Afsaneh Rabiei
8105696	January 31, 2012	US Utility Patent	Afsaneh Rabiei
8110143	February 7, 2012	US Utility Patent	Afsaneh Rabiei
9208912	December 8, 2015	US Utility Patent	Afsaneh Rabiei

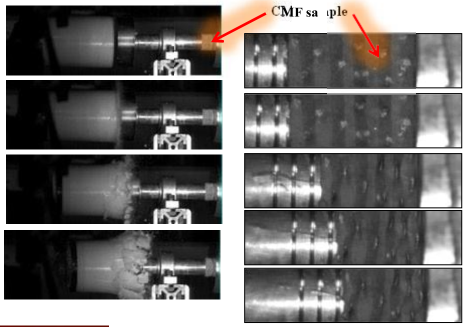
- Composite Metal Foam has 4 issued patents all entitled “Composite MetalFoam and Method of Preparation Thereof”. Shown right.

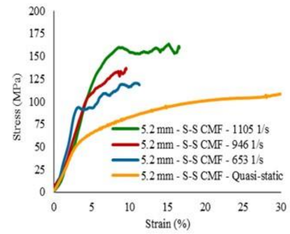
4

CMF Properties Under High Speed Impact

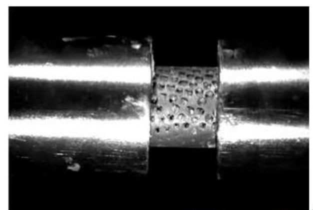
CMF has shown incredible promise as a high-speed impact energy absorber.

COMPRESSION AT IMPACT TESTS up to ≈ 200 - 360 MPH





CMF under 22 m/s impact (60 mph)



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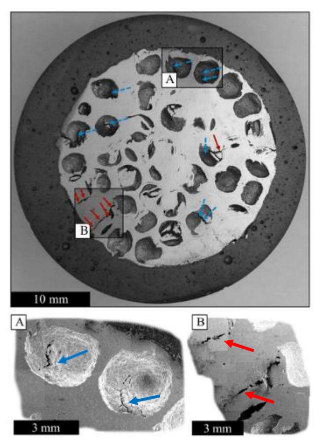
CMF Properties Under High Speed Impact

The hollow metal spheres in CMF act as fine, *sealed pockets of air uniformly distributed* throughout the CMF structure and can dampen the impact, blast-wave, fragments, and ballistic threats, and can protect against extreme heat, fire, vibration, and radiation.

Cross section of a CMF sample after a high-speed impact test with up to 40% compression perpendicular to the plane of the image show:

- The *sealed pockets of air resist the pressure*, like a sealed can of soda.
- Once the pressure passes a critical point, it will burst through the steel spheres (blue arrows) and
- The air will penetrate through the matrix to escape the material (red arrows).
- The resistance to this escaping air provides CMF with



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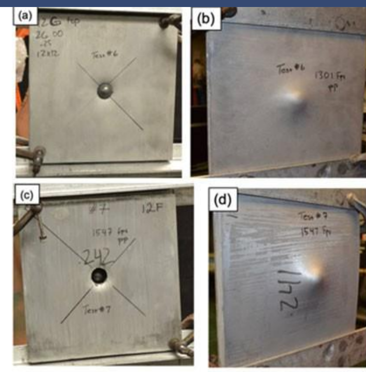
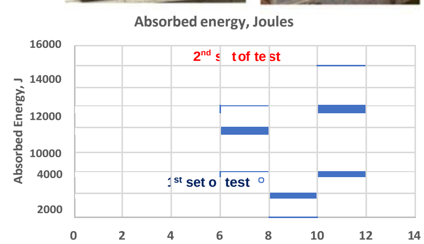
CMF Sandwich Panel Puncture Resistance

- (a) and (b), the strike and back face of the CMF core sandwich panel absorbing over 10,000 Joules of puncture energy without any puncture through the panel. (c) and (d), the strike and back face of another CMF core sandwich panel absorbing about 15,000Joules of puncture energy without any complete perforation through the panel.
- Graph shows the puncture energy absorbed by multiple CMF sandwich panels through the 2 sets of puncture tests versus their arealdensity.
- None of these tests caused complete puncture through the panel.





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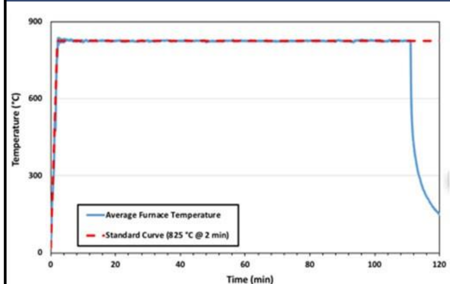
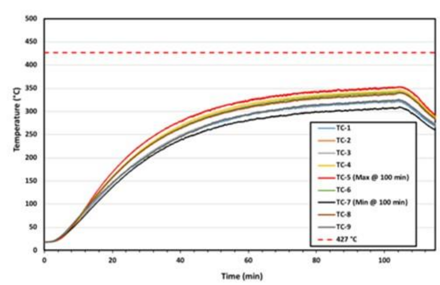
Simulated Pool Fire Testing on CMF





- After 100 minutes of exposure of a 5/8” thick steel Composite Metal Foam to 825ºC, the highest recorded temperature behind the panel was only 379.7 C leaving a large margin to 427ºC standard limit.

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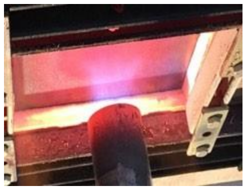
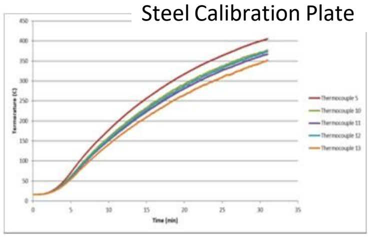
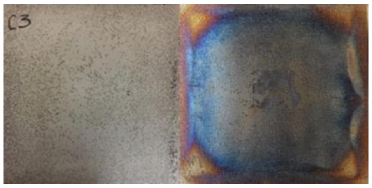
Small Scale Torch Fire Testing on CMF

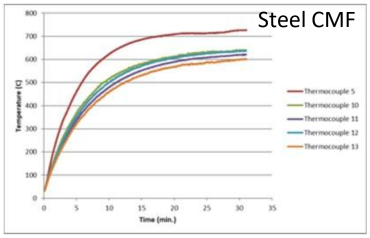
Small scale torch fire testing on 14 mm thick (<5/8") steel CMF showed successful results with the highest temperature behind the panel being 418ºC < 427ºC standard limit.







<5/8" thick CMF before (left) and after (right) exposure to 1200 C for 30 minutes



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CMF Application in Tank Cars

1: Tank car head shields to absorb impact energy.

2: Suspension/roller systems to mitigate vibration and shock.

4: Fittings and fitting protections to reduce weight and increase performance.

5: The interior flame-retardant blanket can be replaced with a layer of CMF, increasing thermal protections with the added benefit of increased impact resistance, vibration absorption, fatigue

*UTLX Tank Car, https://www.american-rails.com/tank.html

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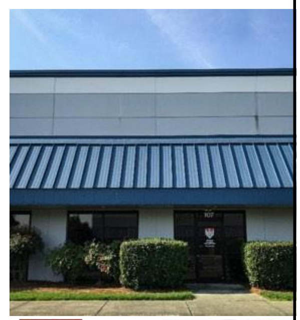
CMF Application in Tank Cars Carrying HAZMAT

- **Task 1:** Kick-off meeting (NCSU)
- **Task 2:** Experimental evaluation of S-S CMF panel's thermal properties (NCSU)
- **Task 3:** Developing two computational models to predict thermal properties of S-S CMF in simulated torch fire testing (NCSU)
- **Task 4:** Manufacturing 1' x 1' S-S CMF panels with thicknesses up to 2" (NCSU)
- **Task 5:** Experimental small-scale dynamic puncture testing (NCSU & TTCI)
- **Task 6:** Welding of S-S CMF, testing of weldments, and optimization of welding parameters (NCSU & AMM)
- **Task 7:** Develop a Finite Element Analysis Model to simulate the small-scale dynamic testing (TTCI & NCSU)
- **Task 8:** Tank car acquisition and conduct large-scale dynamic puncture testing (NCSU)
- **Task 9:** Full-scale simulated Torch Fire testing in duplicate (NCSU & TTCI?)
- **Task 10:** Preparation of final report (NCSU, AMM, TTCI)



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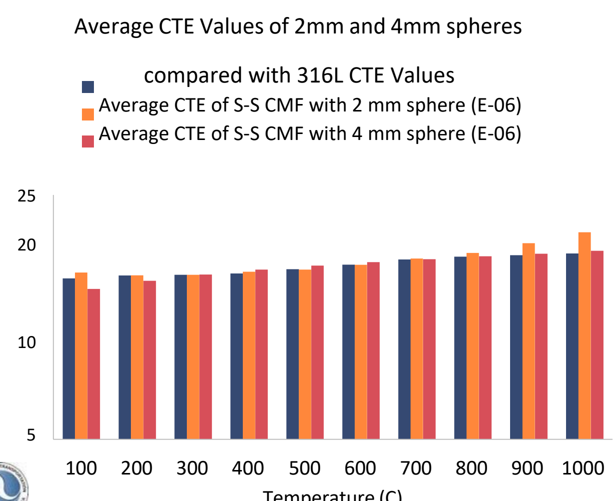
Coefficient of Thermal Expansion of CMF



- CTE of Steel CMF is within the same range as that of the CTE of its parent material with less than 10% difference only.
- All data indicate a good level of repeatability with an average standard deviation of 0.43E-06.
- It also shows that there is not much of a big difference between the CTE of S-S CMF made with 2 mm and 4 mm hollow spheres

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Thermal Conductivity of CMF

Discovery Laser Flash DLF 1200 was used to evaluate the thermal conductivity & diffusivity of steel CMF

Compared to its parent material (316L), Steel CMF's **density is 1/3rd**, its **thermal conductivity and diffusivity are 1/6th and ½ , respectively**!

ANSYS- Fluent software is now being used to develop the computational model for thermal conductivity of CMF at temperatures up to 1200ºC.

	Thermal Properties of Solid 316L Solid Stainless Steel			Thermal Properties of 316L S-S CMF	
Temperature, C	Diffusivity, mm²/s	Specific Heat, $JK^{-1}g^{-1}$	Conductivity, W/m C	Experimental Diffusivity, mm²/s	Experimental Conductivity, W/m C
25	3.6	0.47	13.4	2.317±.045	2.920±0.05
100	4.0	0.49	15.5	-	-
196	4.3	0.52	17.4	2.573±0.087	3.570±0.10
300	4.6	0.54	19.4	-	-
398	5.0	0.56	21.3	2.880±0.090	4.230±0.10
500	5.3	0.57	23.4	-	-
598	5.4	0.59	24.3	3.203±0.054	4.96±0.10
699	5.5	0.60	25.1	3.373±0.119	5.35±0.18
823	5.7	0.63	27.3	3.653±0.141	5.92±0.25
896	5.8	0.64	27.6	3.707±0.181	6.14±0.26
996	5.9	0.66	28.3	3.773±0.218	6.39±0.32

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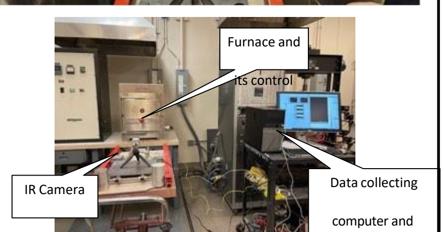
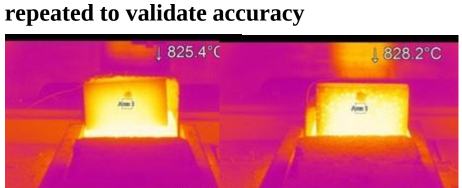
Coefficient of Thermal Expansion of CMF

- Surface Emissivity of CMF was conducted per ASTM E1933 based on surface temperature and emitted radiation.
- The surface temperature was measured with 0.81 mm diameter (30 AWG), K type (chromel-alumel)
- The emitted radiation was measured with an OPTRIS P1M infrared camera,
- CMF emissivity was measured to vary around 0.9. **Further test is being repeated to validate accuracy**





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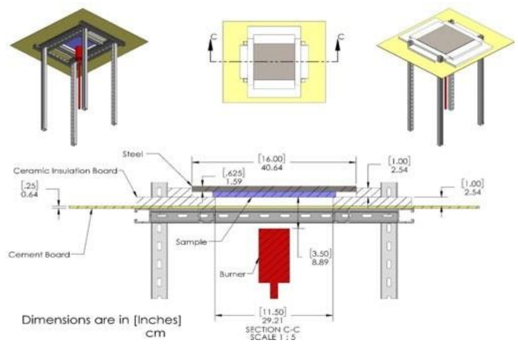
Computational Model of Small-Scale Torch Fire testing of CMF

- Previously a small scale experimental torch fire test was conducted on steel CMF panels of 30 x 30 cm in accordance with 49 CFR Part 179 with a gas temperature of 1204 ± 55.6ºC (2200 ± 100ºF) and velocity of 17.9 ± 4.5 m/s (40 ± 10 mph) at the sample location.
- A computational domain was setup in FDS with mesh sizes of 9.1mm in the X and Y and 9.4mm in the Z direction with a total number of 123,904 cells.
- To simulate the torch, the burner was placed 8.89cm from the calibration carbon steel plate as done in the scaled down experimental test.



Simulated torch fire set up

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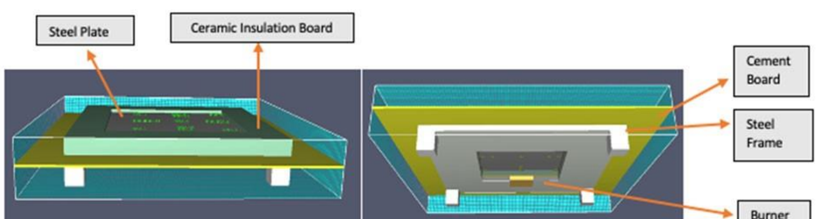
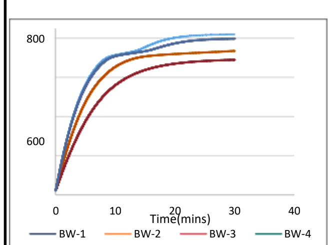
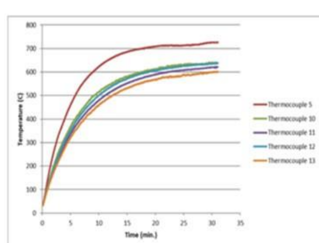
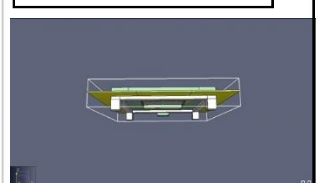
Computational Model of Calibration Small-Scale Torch Fire testing of CMF







Calibration of Carbon Steel Plate



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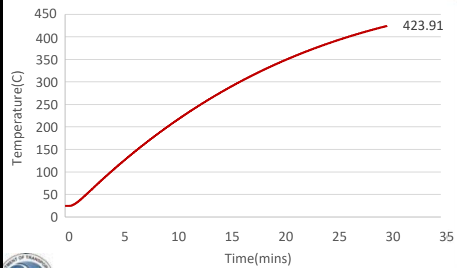
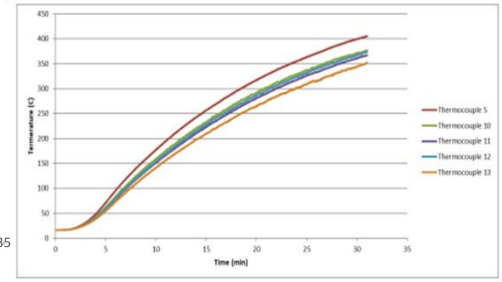
Computational Modeling of CMF's Thermal Behavior



Scaled Down Torch Fire FDS Model



Scaled Down Torch Fire Experiment

- FDS was used to predict the response of CMFs
- the center thermocouple is modeled as this will have the highest temperature reading, based on the calibration run
- More advanced computational models are being developed to predict CMF response in the torch fire test with higher accuracy.
- Once ANSYS-Fluent thermal conductivity model is completed, it will also be used to better predict the performance of CMF in torch fire testing condition

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Welding CMF (AMM)

- Advanced Materials Manufacturing (AMM) is a limited liability start up in Raleigh NC that span off from NCSU to commercialize CMF.
- AMM is tasked to:
  - **Weld** steel CMF,
  - **Manufacture 4' x 4'** CMF panels for torch fire testing
  - Conduct full scale torch fire testing
- So far AMM has been successfully welding CMF panels of various thicknesses up to 1".
- AMM is capable to manufacture 4' x 4' panels in **low cost** for various pplications

Panel	Sphere Size	Thickness mm	Welding Technology	Welding Result
C	4 mm	10.7 10.7	Friction Stir Welding	Unsuccessful Welding
D	2 mm	25.4 25.4	Friction Stir Welding	Unsuccessful Welding
C	4 mm	10.6 10.6	Induction	Successful Welding
		10.6 10.6	Induction	Successful Welding
A	2 mm	22.5 22.5	Induction	Marginal Welding
		22.5 22.5	Induction	Successful Welding
B	2 mm	15.2 15.2	Induction	Successful Welding
		15.2 15.2	Induction	Successful Welding
E	2 mm	10.2 10.2	Induction	Successful Welding
		10.2 10.2	Induction	Successful Welding
F	2 mm	17.7 17.7	Induction	Successful Welding
		17.7 17.7	Induction	Marginal Welding

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Welding of Composite Metal Foam (AMM)

- Steel CMF has been successfully welded using **induction welding** technique.
- Bulk properties have been retained across the weld line.
- Little to no CMF discoloration, distortion, or other damage from the welding process.
- Panels up to 1" in thickness can now be joined quickly, effectively, and inexpensively.

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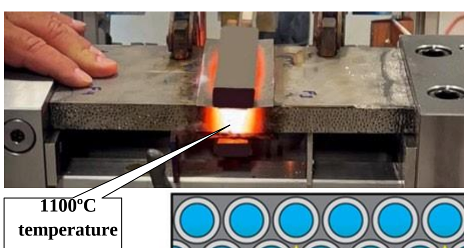
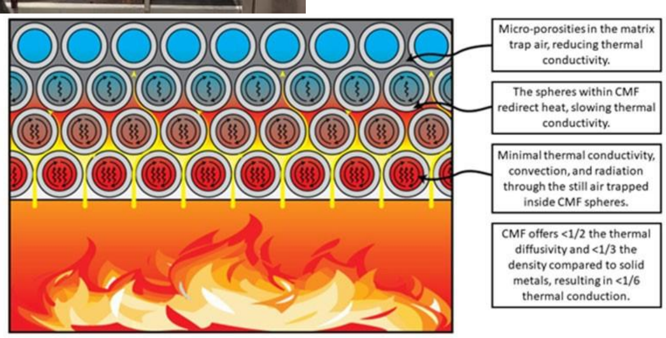
Welding of CMF (AMM)



The steel-CMF panel remains at room temperature only about 3 inches away from white-hot temperature of 1100ºC (2000ºF)!

(Images courtesy of AMM)



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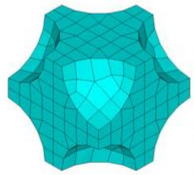
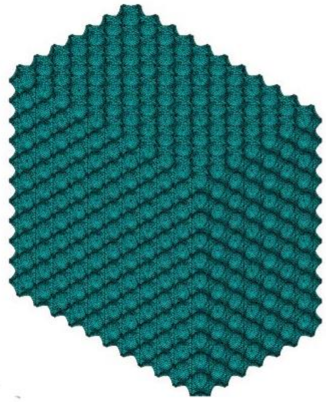
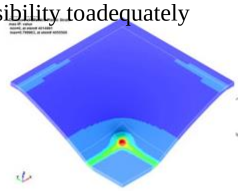
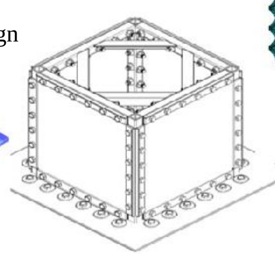
Computational Modeling CMF Performance in Small Scale Puncture Test (TTCI)

- Explored manual controlled CMF meshing: single cell seed model (left), and 11x11x7 model (right).
- First option for the fixture is a cubic frame shown below
  - An FEA model will be developed to evaluate the design for feasibility toadequately









Baseline model (1/4 symmetry):

12"x12" Indenter with 1" radius, 3'x3'x0.563" plate

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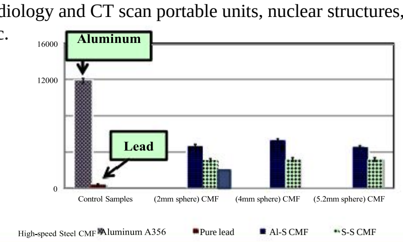
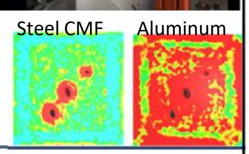
Other Potential Applications of CMF

Transportation of radioactive material, protection of radiology and CT scan portable units, nuclear structures, etc.



Transportation of explosives:

9 psf CMF against three consecutive explosions, fragments impacted on the CMF @ 5000 ft/s velocity. Compared to the same weight aluminum (Right), CMF panel (Left) absorbed all frags with no stress! **Absorbs shock,**



Protection of sensitive structures against ballistic threats.

M2 Partial Penetration (in flight); The hollow spheres crush and

100+ times higher impact energy absorption plus low weigh can provide accident protection for and all moving structures against impact

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Summary

- New classes of materials come about **very rarely** and this brand new and potentially **world-changing class** of materials stands to revolutionize the materials industry.
- There are truly **countless possible use cases for CMF** that would benefit both the defense and civilians.
- Nearly **any application that uses metals** today could be replaced with CMF, increasing the

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Future Work

Status of all tasks of the current project:

- **Task 1:** Kick-off meeting (completed)

Task 2: Experimental evaluation of S-S CMF panel's thermal properties (done & more in progress)
Task 3: Developing two computational models to predict thermal properties of S-S CMF in simulated torch fire testing (in progress)
Task 4: Manufacturing 1' x 1' S-S CMF panels with thicknesses up to 2" (done & more in progress)
Task 5: Experimental small-scale dynamic puncture testing (not done yet)
Task 6: Welding of S-S CMF, testing of weldments, and optimization of welding parameters (successfully done & more in progress)
Task 7: Develop a Finite Element Analysis Model to simulate the small-scale dynamic testing(in progress)
Task 8: Tank car acquisition and conduct large-scale dynamic puncture testing (not done yet, looking for donation of tank cars as well)
Task 9: Full-scale simulated Torch Fire testing in duplicate (not done yet)
Task 10: Preparation of final report (not done yet)

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Thank you

I would be happy to answer any questions

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7.4.2 PHMSA Packaging Initiatives Summary – APT Research

PHMSA Packaging Initiatives Summary – APT Research
Melissa Emery
Director Safety Engineering and Analysis Center (SEAC)

U.S. Department of Transportation
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Agenda/Topics

- APT Research Inc Intro
- Summary of:
  - Damaged/Defective Charge Storage Devices (Lithium Battery) packing research/recommendations
  - Bio-fuels packaging research/recommendations
  - Mitigation of package rupture (fire containment)
- Closing

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APT Research Intro

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APT Research Inc Background Intro

- Small Business--Supports an extensive array of safety and mission assurance functions, including risk management and explosives safety
- Currently PHMSA DOT certified lab
  - 5 Hazard Classifiers on staff
- Other PHMSA research/product development projects include:
  - Risk Management
    - Population Risk for Explosives Transportation by Truck (PRET-T)
  - Unmanned Aerial System (UAS) Hazardous Material (HM) Transport Regulations
  - First Responders Guidebook App

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Classification and Transportation of Defective and Damaged Charge Storage Devices- (TA-2)

(Final Report submitted 10/2020)

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Classification and Transportation of Defective and Damaged Storage Devices (TA-2)

- Development of methods and classification-safe transport of defective and damaged charge storage devices (focus on Lithium ion (Li-ion) batteries
  - Including recommended packaging standard

Lithium Fire Guards PG100

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Classification and Transportation of Defective and Damaged Storage Devices (TA-2)

Table 7: Summary of Testing

Container Requirements	Procedure	Test Event	Pass Criterion
1. Ability to contain effluents	Water indicating paper placed inside the container before the test. Water sprayed on the container from multiple angles post-test.	Drop Vibration Altitude	Water indicating paper not activated
	No visible or detected outgassing	Thermal	Visual and sensory inspection

Table 14: Effectiveness of Testing to Assess Candidate Containment Devices

Container Test Requirements	Effective to Assess Candidate Containment Devices
1. Ability to contain effluents	Yes
2. Ability to contain fire	Yes
3. Ability to contain fragments	Yes
4. Surfaces of the container will not reach levels that personnel	
5. Release of hazardous or corrosive material from t be contained	
6. Batteries will be secure in the container and not lo	

Table 15: Recommended Changes to 49 CFR § 172.101 Hazardous Materials Table for Lithium Ion Batteries

Symbols (1)	Hazardous material descriptions and proper shipping names (2)	Hazard class or Division (3)	Identification Numbers (4)	PG (5)	Label Codes (6)	Special Provisions (172.102) (7)	(8) Packaging (§173.***)			(9) Quantity Limitations (see §§173.27 and 175.75)		(10) Vessel Stowage	
							Exceptions (8A)	Non-bulk (8B)	Bulk (8C)	Passenger Aircraft (rail) (9A)	Cargo Aircraft Only (9B)	Location (10A)	Other (10B)
	Lithium ion batteries including lithium ion polymer batteries	9	UN3480	....	9	388, 422, A54, A100	185	185	185	Forbidden	35 kg	A	
	Lithium ion batteries contained in equipment including lithium	9	UN3481	....	9	181, 388, 422, A54	185	185	185	5 kg	35 kg	A	

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Classification and Research of the Transportation of Bio-Derived Fuel- TA-4

(Final Report Submitted 3/21)

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Classification and Research of the Transportation of Bio-Derived Fuel (TA-4)

- Conduct research and testing on biofuels packaging compatibility
- Biofuels for study:
  - Ethanol
  - Methanol
  - Biodiesel
  - Syngas
  - Algae-derived biofuel
- Identify the most suitable packaging types for each biofuel
    - No degrading
    - Containment
  - Provided industry guidelines for transporting
  - Provided regulatory approaches for transport

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Classification and Research of the Transportation of Bio-Derived Fuel (TA-4)

A-P-T Research, Inc. Final Report

Table 39: Characterization and Classification of Bio-Derived Fuels

Characteristic	Classification/Recommendation
The biofuel can be transported in a tanker.	The tanker should be equipped with the following: • Pressure and vacuum relief • Internal valving to the tanks • Vapor recovery systems • Breakaway piping • Remote shut-off controls • Pressure and temperature ga • Level gauges

A-P-T Research, Inc. Final Report

Table 40: Potential Hazards and Recommended Regulation Approaches During Transport

Biofuel	Biofuel Hazard Category	Potential Hazard	Recommended Regulating Approach During Transport
Ethanol	High	Pressurization Ethanol vapors can accumulate in the container and create pressure. It has a relatively high vapor pressure.	Pressure and vacuum relief devices should be incorporated
		Leaks/Ruptures If ethanol is spilled, it can initiated	
		Contamination/Compatibili Ethanol is incompatible wi	

14.4 POTENTIAL PACKAGING SOLUTIONS

Based on research results, the team developed biofuel packaging characteristics, which are important to better ensure safety to personnel, equipment, and facilities during transport operations. A summary of these characteristics is provided in Table 36.

Table 36: Container Recommendations

Biofuel	Recommended Container Materials	Container Materials to Avoid	Pressure Venting	Temp Control or Insulation	Special Considerations
Ethanol	• Carbon steel • Stainless steel • Thermoset-reinforced fiberglass • Thermoplastic piping • Thermoset-reinforced	• Polyurethane • Zinc • Brass • Lead • Aluminum • Terne plate steel • Natural rubber • Cork gasket • Leather	Yes	Not required (unless long term storage in containers anticipated – Reference Sections 14.1.1 and 14.2.1)	• Bonding and grounding are needed • Internal or external floating roofs or inert gas blanket should be incorporated • Leak detection is recommended

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Mitigating the Risks and Consequences Associated with Hazardous Material Package Rupture

- RM-4

(Final Report submitted 03/2021)

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Mitigating the Risks and Consequences Associated with Hazardous Material Package Rupture (RM-4)

- Develop and demonstrate new design features for implementation onto cargo tanks for transport of E&PC
  - Reduce possibility of explosion in a fire event (confinement)
- Designed a thermally initiated venting system
  - 2 prototypes
    - Bismuth-Tin shear ring
    - Pin-Puller Hinge
  - Bismuth-Tin Shear Ring vent design leading candidate for continued research/implementation
    - Simple, reliable, ease of scaling

Pin puller design

Bismuth-Tin Shear Ring

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Closing

- Interested in supporting/continuing packaging efforts in the area of:
  - Charge storage devices (e.g., Li-ion Battery)
  - Bio-fuels
  - Package rupture (fire containment)

- Contact: Melissa Emery
  (256) 327-3396
  memery@apt-research.com

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7.4.3 Thermo-Mechanical Responses of FRP Composite Jacketing for Tank Cars Under Impact and Fire Presentation Slides

Thermo-Mechanical Responses of FRP Composite Jacketing for Tank Cars under Impact and Fire

Team Members

Dr. Hota GangaRao
Dr. Ray Liang

Dr. Yoojung Yoon
Dr. Rakesh Gupta

Dr. Chao Zhang
Andrew Kenney
Lekhnath Bhandari
Mohamed Omar

Introduction

- U.S Department of Transportation (USDOT) has a project goal to improve the performance of various hazardous materials packaging in transportation by applying advanced materials and designs.
- The interdisciplinary research team at the West Virginia University Constructed Facilities Center (WVU-CFC), in cooperation with research partners, proposes an innovative multifunctional composite panel as a jacket for tank cars to address this problem.
- The capabilities of WVU-CFC are based on over 100 man-years in combined development and characterization experience of composite panels via long-term research on polymer composite and hybrid material components.

Project Relevance

China tanker truck explosion leaves at least 20 dead, nearly 200 hurt, over 200 rooms damaged

June 13, 2020, Zhejiang, China

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Mission Statement

The multifunctional jacket (Fig. 1) wrapped over stainless steel tank wall (7) will consist of a layer of high-density polyurethane foam

(5) sandwiched between multiple layers of Kevlar reinforced polyurethane FRP (4 and 6), glass fiber reinforced vinyl ester layer (3), intumescent coating (2) and outermost sacrificial vinyl ester GFRP layer (1)

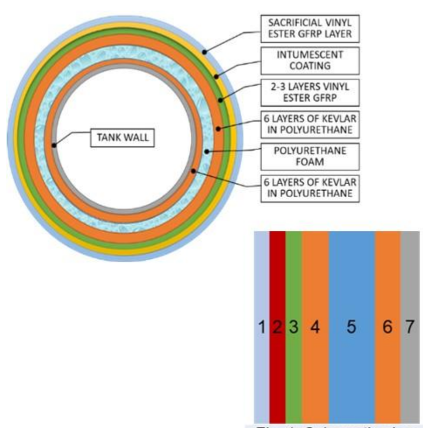

Fig. 1. Schematic view of the multifunctional jacket.

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Objectives

- Manufacturing of test samples
- Evaluation of samples for optimal performance
- Curvilinear jacket manufacturing
- Testing and evaluation of curvilinear jacket
- Puncture and impact test with a tank car jacketed by the proposed FRP curvilinear jacket
- Fire resistance testing
- Cost-benefit analysis, including AAR practicability evaluation

5

Objectives

Table 4: Tank Jacket Test Matrix

Manufacturing Method	Needle Punch of Comp Only	Fabric Config.	Type of Test								
			Tension	Comp.	Bending	Shear	Puncture	TC	Thermal Coeff.	Accel. Aging	Bond Pull-out
Vacuum Infusion	Yes	Type 1	3	3	3	3	3	3	3	9	3
	Yes	Type 2	3	3	3	3	3	3	3	9	3
	No	Type 1	3	3	3	3	3	3	3	9	3
	No	Type 2	3	3	3	3	3	3	3	9	3
Filament Winding	Yes	Type 1	3	3	3	3	3	3	3	12	3
	Yes	Type 2	3	3	3	3	3	3	3	12	3
	No	Type 1	3	3	3	3	3	3	3	12	3
	No	Type 2	3	3	3	3	3	3	3	12	3
Bonded to Steel			No	No	No	No	Yes	No	No	Yes	Yes

Abbreviation:
Config. – Configuration; Comp. – Compression; TC – Thermal Conductivity; Coeff. – Coefficient; Accel. - Accelerated

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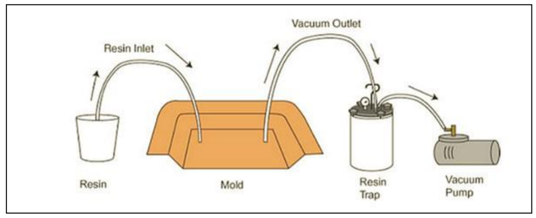
Background on Vacuum Infusion Process

- The Vacuum Infusion Process (VIP) is a method of infusing porous material using a vacuum pump
- Used in industry to produce complex, high quality composite pieces



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Background on Vacuum Infusion Process

- Benefits
  - Higher fiber volume fraction
  - Higher strength and stiffness
  - Low amount of voids/entrapped air
  - Consistent, high-quality results
  - Unlimited set up time
  - Can be formed against complex molds to create intricate parts
- Drawbacks
  - Involved setup
  - Requires practice to ensure high quality parts
  - Requires disposable supplies

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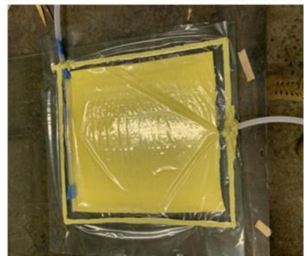
Manufacturing Process

- Manufacturing Steps
  - Clean off and prepare infusion surface
  - Cut and place flow media on top of infusion layers
  - Create airtight perimeter around fabric
  - Cut and place inlet and outlet tubing
  - Apply plastic peel ply



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Manufacturing Process

- Once peel ply is attached, a "dry" vacuum test is performed
- Any air leaks can be fixed with additional sealant putty
- Vacuum strength can greatly affect quality of sample
  - With current setup, average vacuum pressure is 26 in/Hg
  - Equivalent to 100 Torr or ~ 87% vacuum
- Infusing time primarily dependent on resin viscosity
  - Number of layers, vacuum pressure, layer material, size of layers also influence speed

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Manufacturing Process

- After sample is fully saturated, the vacuum is turned off
  - Inlet and outlet tubing is cut, ends sealed off
- Post curing pressure conditions also affect final quality of infusion
- Cure time of resin depends on amount of accelerator used and temperature
  - Fully cures within 24 hours at room temperature
- After sample is fully cured, the flow media can be removed, and the specimen is ready for testing

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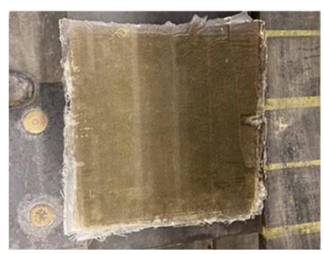
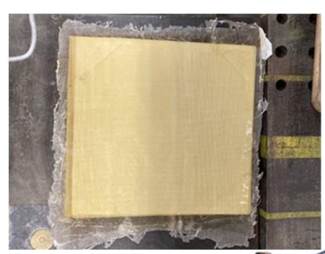
Sample Production

- Current work is currently focused on testing different configurations of layers and core materials
- The standard layup of fabric is currently 12 layers total
  - 8 L GFRP, 4 L Kevlar (Glass, Kevlar, Glass x4)
  - Symmetric around core material
- Other variable include resin choice, stitching, flow media, core material, core size





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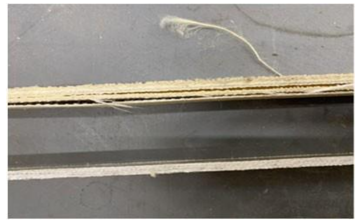
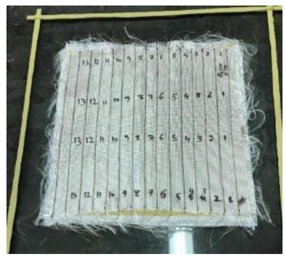
Stitching of Fabric Layers

- Large amount of interlaminar shearing occurs when cutting samples into test sizes
- Bonding between glass layers the resin is excellent, poor for Kevlar
- Stitching of the fabric increases cohesion between layers





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Core Material

- Another variable currently being experimented with is the choice of core material & thickness
- Initial choice was a type of polyurethane foam
- Thin elastomeric pads have also been used as the core material

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Choice of Resin

- One of the newer variable being tested is the choice of resin used
- Currently, an unsaturated polyester resin has been the focus of most testing
  - 1% MKEP by volume (Methyl ethyl ketone peroxide)
  - Cobalt Naphthenate used as an accelerator
- A two-part epoxy-based resin is being experimented with, in order to increase bonding in Kevlar layers

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Sample Testing (Tension)

- Following ASTM D3039
- Instron 8501 @ 0.15 in/min
- Samples were pulled until failure
- Time, position of clamps, and load were recorded for analysis
- Metal tabs placed on the ends to prevent a crushing failure

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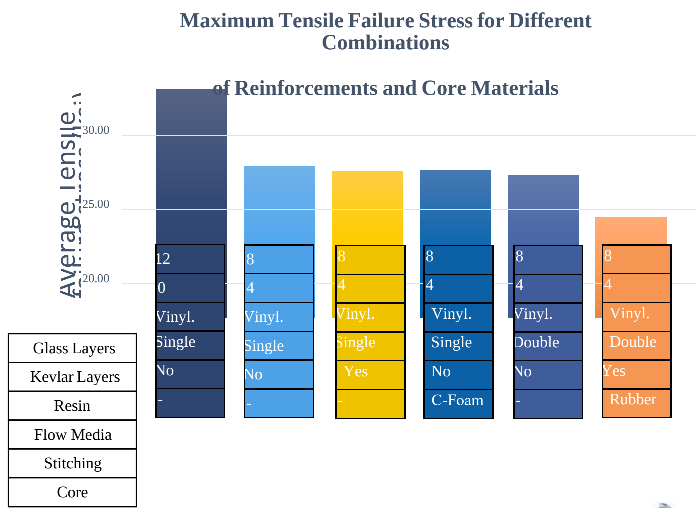
Sample Testing (Tension)



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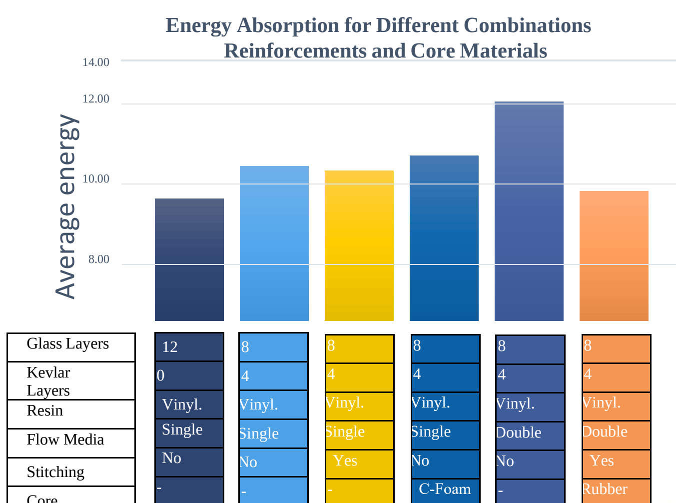
Sample Testing (Tension)



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Sample Testing (Tension)

Difference in Failure Modes

12L GFRP Sample 4

8L GFRP, 4L Kev. Sample 3

12L GFRP Sample 2

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Sample Testing (Bending)

- Following ASTM D7264
- Instron 8501 @ 0.20 in/min
- Samples bent until failure
- Time, position of clamps, and load were recorded for analysis
- Data points were collected every 0.1s

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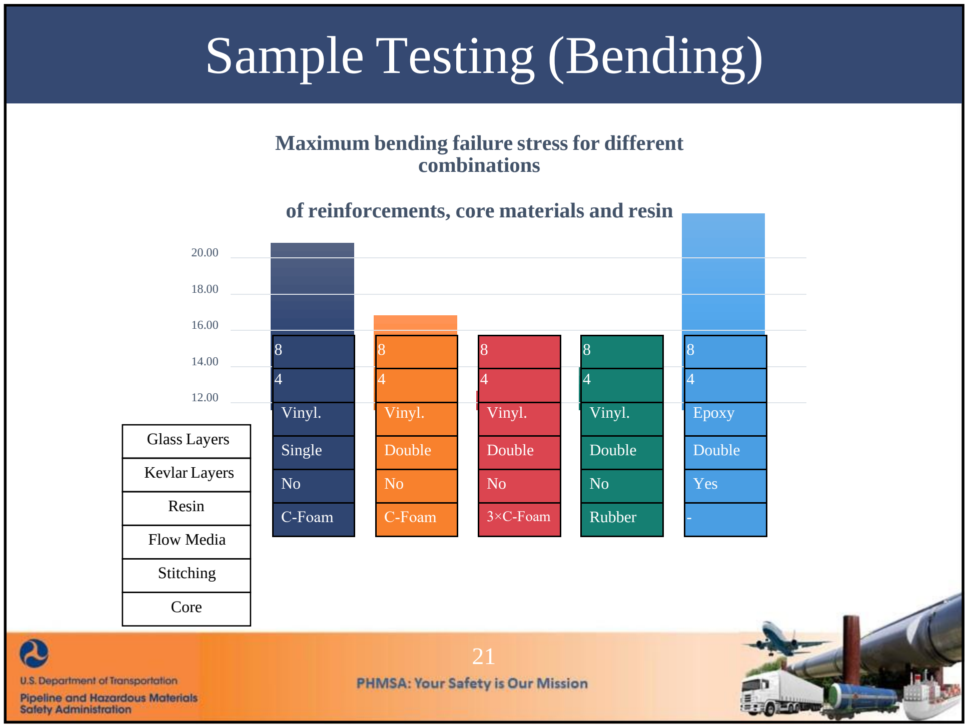
Sample Testing (Bending)
Maximum bending failure stress for different combinations
of reinforcements, core materials and resin
20.00
18.00
16.00
14.00
12.00
Glass Layers
Kevlar Layers
Resin
Flow Media
Stitching
Core
8
4
Vinyl.
Single
No
C-Foam
8
4
Vinyl.
Double
No
C-Foam
8
4
Vinyl.
Double
No
3×C-Foam
8
4
Vinyl.
Double
No
Rubber
8
4
Epoxy
Double
Yes
-
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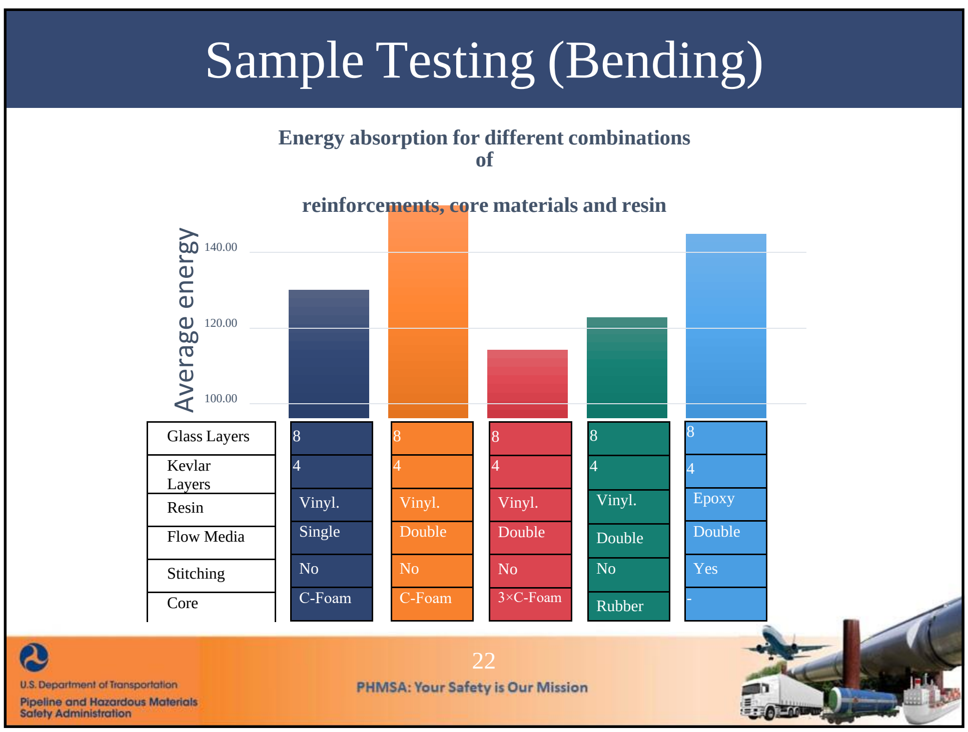
Sample Testing (Bending)
Energy absorption for different combinations of
reinforcements, core materials and resin
Average energy
140.00
120.00
100.00
Glass Layers
Kevlar Layers
Resin
Flow Media
Stitching
Core
8
4
Vinyl.
Single
No
C-Foam
8
4
Vinyl.
Double
No
C-Foam
8
4
Vinyl.
Double
No
3×C-Foam
8
4
Vinyl.
Double
No
Rubber
8
4
Epoxy
Double
Yes
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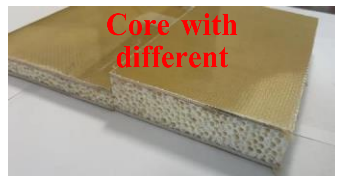
Impact and Puncture Testing

Drop Height = 20 inch
Impact velocity = 27 inch/s
Impact Weight = 6kg

ASTM D7136-15/ 5628



Infused Samples

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Impact and Puncture Testing

12 Layer Glass

8L Glass 4L Kevlar,
1” PU Core

8L Glass 4L Kevlar,

- Preliminary testing show the induced cracks/matrix failure on the front surface around the impact region

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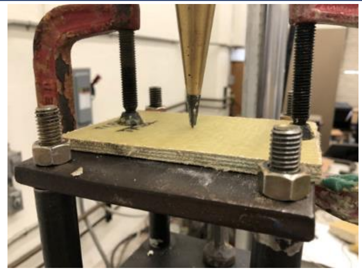
Impact and Puncture Testing

- Puncture testing performed using needle attached to Instron grip (5 mm/min)
- Energy absorption measured from displacement and force
- Presented in terms of unit thickness



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Specimen Name	Core Material	Resin Type	Total energy absorbed (in. lb.)	Thickness (in.)	Energy per unit thickness (in.lb./in.)
C-Foam	C-Foam	n/a	10.15	0.2240	45.33
PU-Foam	PU-Foam	n/a	104.64	0.3183	328.79
Elastomeric Pad	Elastomeric Pad	n/a	10.84	0.0530	204.58
CFP1	C-Foam	Vinyl Ester	498.55	0.1760	2832.66
TCFP1	Triple Layer C-Foam	Vinyl Ester	602.07	0.3230	1864.00
RCP1	Elastomeric Pad	Vinyl Ester	604.14	0.2465	2450.89
SFP1	PU-Foam	Vinyl Ester	858.67	0.4096	2096.35
EFP1	NA	Epoxy	643.35	0.1560	4124.04
VEP1	NA	Vinyl Ester	459.72	0.1690	2720.22

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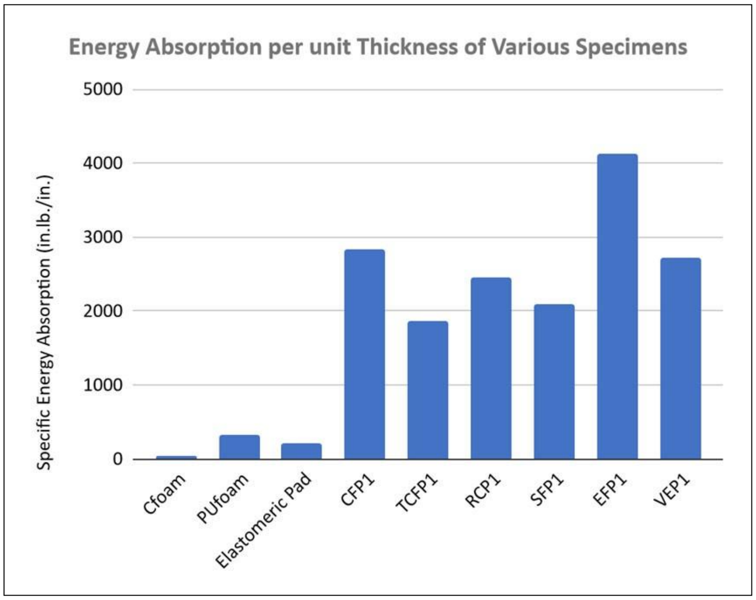

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Future Work

- Perform and analyze data from the impact and puncture tests
- Develop ideal combination of fabric layup, core material, and resin choice
- Continue work simultaneously on other project objectives
  - Fire resistance testing
  - Finite element modeling
  - Cost-Effectiveness analysis
  - Resin flow equations and modeling

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Concurrent Progress

- Fire Retardant Properties and Testing
  - Alongside the current structural testing and development
  - Current developments include
  - Fire resistance of final proposed jacket will be ensured through ASTM procedures
    - ASTM E1529 – Simulated hydrocarbon pool fire test
    - ASTM E2707 – A direct flame impingement test (Torch Test)
  - Larger scale test will also be performed later in development in collaboration with NIST

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Concurrent Progress

- Finite Element Modeling
  - Data from the experimental testing will be validated through a finite element (FE) model
  - The modeling will be used to ensure accurate material properties for the curvilinear panels
  - FE analysis will also be used to simulate puncture tests on the composite layup
  - The WVU research team will use testing and FE modeling completed by TTCI to further validate data
    - 2013 DOT-111 Test
    - 2016 DOT-117 Test

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Concurrent Progress

- Cost-Effectiveness Analysis
  - Detailed study into the feasibility and advantages of this approach as compared to other similar solutions
  - First step is to identify key categories important to the project
    - Economic Analysis
    - Technical Performance
    - Practicability
  - Each category is subdivided into its components to allow for a numerical comparison between methods
  - The strengths and weaknesses of each solution can then be compared from these weighted values

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Concurrent Progress

- Refinement of Infusion Process
  - In order to accurately predict the final quality of the infused composite, the flow of the resin through the material is being studied
  - By controlling and monitoring several key factors in the infusion, equations are being developed to predict the flow
  - Controlled variables include:
    - Volumetric flow rate
    - Viscosity of the resin
    - Pressure of vacuum
    - Friction from the surface of the material

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